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Development of a novel common-rail type Dimethyl ether (DME) injector

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ABSTRACT

A novel common-rail type DME injector has been proposed by State Key Laboratory of Engines. The injector employs impact principle to enlarge its electromagnetic force, and thus has no plunger matching parts. The sealing and wear problems brought by plunger can be avoided when the injector injects DME. In addition, oil return is absent from the injector which can be directly driven by 24 V. In order to validate the feasibility of the proposed design and investigate the influence of structure parameters on injector performance, a simulation model is established based on Flowmaster coupled Maxwell. An optimized injector prototype is made in accordance with the simulation results. Our experiment shows that the working principle of the injector is effective, and that its performance can meet the requirements of DME fueled engines. Moreover, the novel injector has the advantages of back-pressure insensitive injection quantity and an opening response that is not affected by common-rail pressure.

1. Introduction

The global problems such as dwindling petroleum resources and air contamination by exhaust gases emitted from engines call for increasing efforts to alternative fuels. Dimethyl ether (DME) is recognized as a promising clean fuel that can be used in diesel engines because of its superior self-ignition characteristic [1,2] and wide production coming from a variety of feedstocks such as natural gas, crude oil, residual oil, coal, waste products and biomass [3]. When employed in diesel engines, DME can offer many benefits. First, the cetane number of DME was found to be 55–60 [4], which is much higher than that of conventional diesel fuels, i.e., 40–56. This feature of DME provides mild engine operations with much lower noise by reducing the ignition delay of engine and suppressing rapid premixed burning. Second, DME is characteristic of both high oxygen content (around 35% by mass) and absence of C–C bonds, leading to cleaner combustion and lower exhaust emission levels [5,6]. Many researchers [7–9] have reported that DME fueled engines posses lower hydrocarbon (HC) and carbon monoxide (CO) exhaust emissions as well as soot free combustion. Third, in contrast to conventional diesel fueled engines, it is not necessary for the engine fueled by DME to trade-off between NO_x and particulate matter (PM) emissions [10]. Therefore, by adopting strategies including the optimization of injection timing, multiple injections, EGR, and post-treatment, NO_x emissions from the engine could be significantly reduced without the potential of increasing PM emissions [11,12].

Although the above-mentioned advantages as an alternative fuel for diesel engines, the DME may suffer from a lower viscosity compared with diesel fuels. In addition, it lacks lubricating property that is inherent for gaseous fuels. This could cause leakage from the fuel supply system which relies on small clearances for sealing, as well as increase wear and tear in the engine, especially in the fuel-injection system [13,14]. Edgar et al. [15] have reported that the leakage rate of DME along the plungers can be up to 40–50% of the fuel. Due to leakage problems, currently available fuel-injection systems are not suitable for DME. To address this issue, most sealing materials made of conventional elastomers should be replaced with anticorrosive materials. In addition, due to wear problems, lubricity additives are also required in current fuel-injection system for DME use [16]. Hence, it is crucial to develop a leakage-free and durable injection-system for DME massively used as engine fuels.

There are several works on DME fuel-injection systems that have been carried out in recent years. The two feasible methods of developing a DME fuel-injection system include: (i) modification of conventional pump-pipe-nozzle fuel-injection systems; and (ii) new system with a variable displacement pump or common-rail [13]. Sorenson et al. [17], Hayashi et al. [18] and Sato et al. [19] studied the performance of DME fueled engines using modified conventional pump-pipe-nozzle injection system. Gill and Ofner [20] developed an electric control hydraulic DME injection system. After comparing the characteristic of DME to that of diesel fuel,

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James et al. [21,22] has proposed that the common-rail fuel-injection system is more suitable for DME fueled engines, and developed a common-rail fuel-injection system for DME.

Because of the existence of plunger matching parts, the sealing and wear problems in all the above mentioned fuel-injection systems are still inevitable. In order to ensure the successful operation of the system, appropriate lubricant should be added and the corresponding plunger matching parts need surface hardening. A novel common-rail fuel-injection system for DME has been proposed by State Key Laboratory of Engines. The paper mainly introduces the development of the novel common-rail type DME injector based on the impact principle. Normally, electromagnetic force is directly used to drive the needle valve in the electromagnetic type injector. When the pattern is used in the DME injector, an electromagnet of a large size is needed. This appears to deviate from the installation requirements of engines, and is bound to slower opening and closing response of the injector. The developed injector on the one hand adopts the electromagnetic force, on the

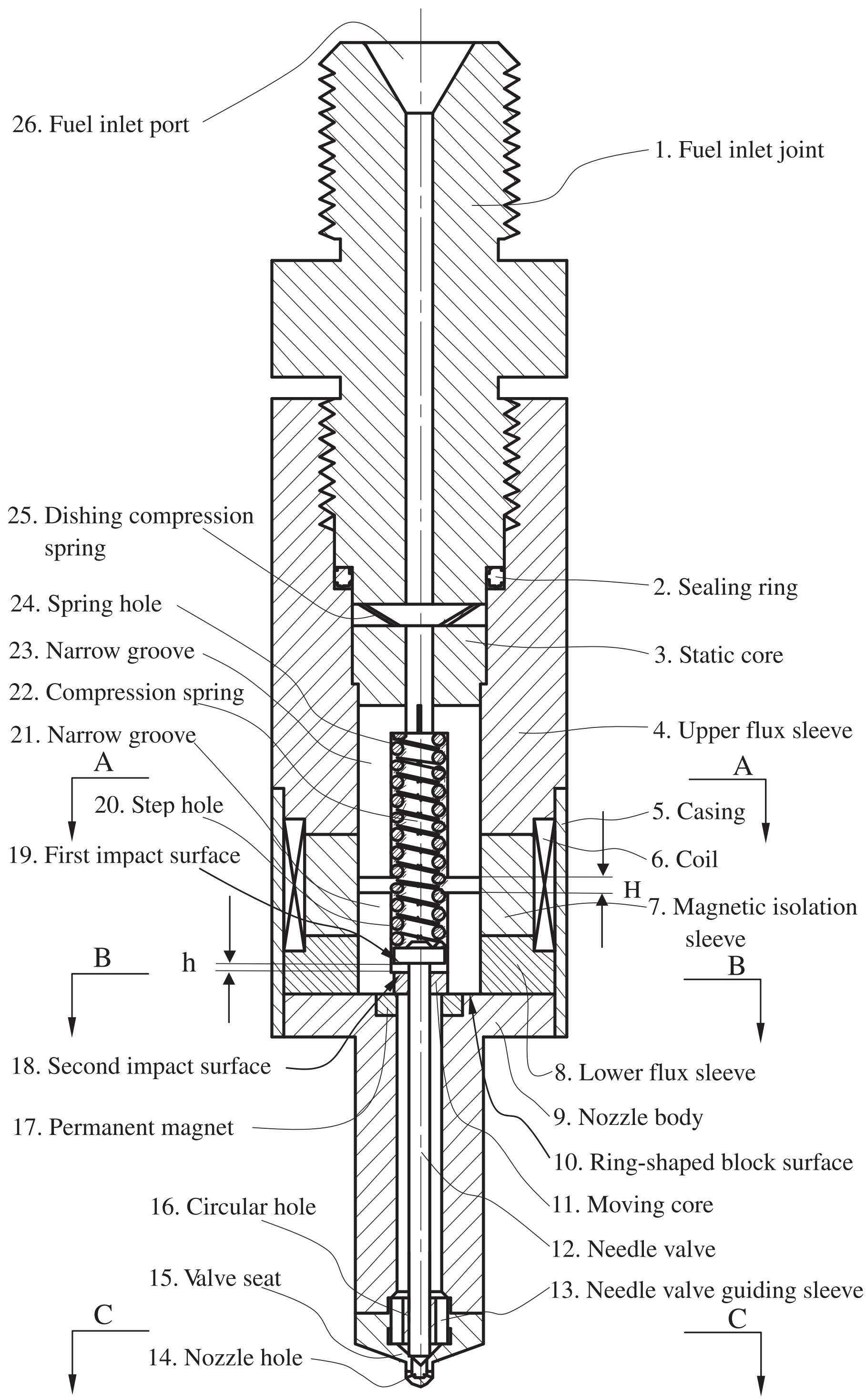

Fig. 1. Sectional view of the novel common-rail type DME injector. (a) Axial sectional view of the injector. (b) Sectional view of the static core along *A–A* direction. (c) Sectional view of the moving core along *B–B* direction. (d) Sectional view of the valve seat along *C–C* direction.