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NUMERICAL STUDY OF A LIGHT-DUTY DIESEL ENGINE WITH A DUAL-LOOP EGR SYSTEM UNDER FREQUENT ENGINE OPERATING CONDITIONS USING THE DOE METHOD

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ABSTRACT−Exhaust gas recirculation (EGR) is an emission control technology that allows for a significant reduction in NOx emissions from light- and heavy-duty diesel engines. The primary effects of EGR are a lower flame temperature and a lower oxygen concentration of the working fluid in the combustion chamber. A high pressure loop (HPL) EGR is characterized by a fast response, especially at lower speeds, but is only applicable if the turbine upstream pressure is sufficiently higher than the boost pressure. On the contrary, for the low pressure loop (LPL) EGR, a positive differential pressure between the turbine outlet and the compressor inlet is generally available. However, a LPL EGR is characterized by a slow response, especially at low and moderate speeds. In this study, of the future types of EGR systems, the dual-loop EGR system (which has the combined features of the high-pressure loop EGR and the low-pressure loop EGR) was developed and was optimized under five selected operating conditions using a commercial engine simulation program (GT-POWER) and the DOE method. Finally, significant improvements in the engine exhaust emissions and performance were obtained by controlling several major variables.

KEY WORDS : Exhaust gas recirculation, Dual-loop EGR, Light-duty diesel engine, Design of experiments, 1D simulation, Boost pressure

1. INTRODUCTION

A diesel engine has many advantages in terms of its fuel consumption, combustion efficiency and durability. Also, a diesel engine emits a relatively small amount of carbon dioxide (CO_2), carbon monoxide (CO) and hydrocarbons (HC). However, diesel engines are a significant source of NOx emissions and particulate matter emissions in urban areas. As the level of environmental concern increases, a reduction of NOx emissions is one of the most important tasks for the automotive industry to overcome. Additionally, future emission regulations will require a significant reduction in both NOx emissions and particulate matter by using EGR and aftertreatment systems. A comparison between experimental results for urban buses equipped with urea SCR and EGR + DPF systems using diesel fuel has been reported in previous studies (López *et al*., 2009). Exhaust gas recirculation (EGR) is an emission control technology that allows for a significant reduction in NOx emissions from light- and heavy-duty diesel engines. The primary effects of EGR (Zheng *et al*., 2004) are a lower flame temperature and a lower oxygen concentration of the working fluid in the combustion chamber.

Because a high pressure loop (HPL) EGR is characterized by a fast response, especially at lower speeds, it is only applicable if the turbine upstream pressure is sufficiently higher than the boost pressure. For a low pressure loop (LPL) EGR, a positive differential pressure between the turbine outlet and the compressor inlet is generally required. However, the LPL EGR is characterized by a slower response than that of HPL systems, especially at low and moderate speeds.

Due to the reinforced regulations, the exhaust gas recirculation system is widely used and is believed to be an effective method for NOx and PM reduction. Regarding the future types of EGR, a newly developed, dual-loop EGR system has become a common option to consider.

The experimental results of dual-loop EGR systems were reported in Cho *et al.* (2008), who studied a high-efficiency clean combustion (HECC) engine compared to the HPL, LPL and dual-loop EGR at five operating conditions.

For the dual-loop EGR system, it has been reported that the determination of the intake/exhaust air fraction (Wang, 2008) and turbocharger matching (Mueller *et al*., 2005; Czarnowski *et al*., 2008) are important. However, there are complex interactions between the variables that affect the

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