Combustion characteristics of a DI-HCCI gasoline engine running at different boost pressures

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Article info
Article history:
Received 10 November 2011
Received in revised form 17 January 2012
Accepted 18 January 2012
Available online 2 February 2012

Keywords:
HCCI engine
Gasoline
Boost pressure
Combustion characteristics
Emissions

Abstract
Homogeneous charge compression ignition (HCCI) combustion mode has some benefits compared to the most popular conventional combustion forms used in the internal combustion (IC) engines: spark ignition (SI) and compression ignition (CI). This combustion mode provides low oxides of nitrogen (NOx) emissions and high thermal efficiency. However, it can produce higher unburned hydrocarbon (UHC) and carbon monoxide (CO) emissions than those of conventional engines due to the lower combustion temperatures. In the naturally aspirated HCCI engines, the low engine output power limits its use in the current engine technologies. Intake air pressure boosting is a common way to improve the engine output power which is widely used in the high performance SI and CI engine applications. Therefore, in this study, the effect of inlet air pressure on the combustion characteristics and exhaust emissions of a direct injection homogeneous charge compression ignition (DI-HCCI) gasoline engine was investigated. For this purpose, a heavy-duty diesel engine was converted to a HCCI direct-injection gasoline engine. The experiments were performed at three different inlet air pressures while operating the engine at the same equivalence ratio and intake air temperature as in normally aspirated HCCI engine condition at different engine speeds. The start of injection (SOI) timing was set dependently to achieve the maximum engine torque at each test condition. The effects of inlet air pressure both on the combustion characteristics (such as cylinder pressure, heat release rate, engine efficiencies, and mean effective pressure) and on the exhaust emissions (such as CO, UHC and NOx) were discussed. The coefficients of variation (COV) of the indicated mean effective pressure (IMEP) were also provided.

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1. Introduction

Direct injection spark ignition (DISI) gasoline engines have better performance and fuel economy than the conventional spark ignition (SI) engines. In these engines, the fuel is injected directly into the cylinder and stratified near the spark plug. This allows for a flame to propagate, and fuel can be consumed with excess oxygen around the flammable fuel charge. The high temperature flame produces oxides of nitrogen (NOx) emissions. Due to the fuel stratification, locally fuel rich regions can produce particulate matter (PM) emissions [1–3]. The combustion strategies are used to improve efficiency generally result in increased NOx emission, while using the combustion strategies to reduce NOx result in increased total unburned hydrocarbon (UHC) and PM emissions or visa versa. Therefore, the current limitations on NOx and PM emissions of DISI engines have stimulated further investigation on alternative combustion systems like homogeneous charge compression ignition (HCCI), which produces little NOx, and minimal PM emissions by operating overall lean. HCCI combustion has some benefits compared to conventional SI and compression ignition (CI) engines, such as low NOx emission and high thermal efficiency. However, this combustion mode can produce higher UHC and carbon monoxide (CO) emissions than those of conventional engines [4].

In SI and CI engines, the start of combustion timing can be controlled with spark timing and fuel injection timing, respectively, but the HCCI engine does not have a direct method to control the start-of-combustion timing. Therefore, it is important to control the combustion for best fuel economy and lowest emissions. In controlling the temperature, pressure and composition of the in-cylinder mixture, the following parameters can be used to affect the combustion phase of the HCCI engine: fuel characteristics, intake air temperature, air–fuel ratio, fuel injection timing, multiple pulse fuel injection, engine speed, and boost and back pressure. In addition, the engine performance is influenced by the injector spray geometry, exhaust gas recycling (EGR), variable valve timing, swirl ratio, supercharging, compression ratio, and the piston-cylinder geometry [5].