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Emissions Control Challenges for Compression Ignition Engines

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Abstract

As emission standards continue to evolve, it is clear that future engine control strategies will involve the integration of combustion optimization, fuel refinement and advanced exhaust after-treatment technologies. The West Virginia University (WVU) Center for Alternative Fuels Engines and Emissions (CAFEE) continues to engage the challenge of future regulation in a multi-pronged approach, investigating advanced combustion regimes, alternative fuels, and next-generation emissions control technology. Results presented herein summarize recent regulatory challenges for compression ignition engines and discuss future pathways.

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Keywords: Engines; Diesel; Emissions;Greenhouse Gas; Alternative Fuels, Biofuels

1. Introduction

Modern Compression Ignition (CI) engines, commonly referred to as diesel engines, face continually evolving challenges with respect to meeting United States federal- and state-mandated exhaust emissions and fuel consumption standards. Throughout the last two decades, diesel engine and exhaust aftertreatment technology has advanced significantly to meet increasingly strict regulations, particularly with regards to oxides of nitrogen (NO_X) and particulate matter (PM). The difficulty in reducing these particular emissions constituents lies in the proverbial NO_X versus PM tradeoff; in essence engine control strategies that reduce NO_X emissions in turn increase PM emissions and vice versa. Although this tradeoff still exists from an engine perspective, exhaust aftertreatment systems such as selective catalytic reduction (SCR) and diesel particulate filters (DPF) provide a means to simultaneous reduce tailpipe emissions of NO_X and PM, albeit at an increased cost of technology, fuel for DPF regeneration, diesel exhaust fluid (DEF) for SCR operation, and system maintenance. In recent years, fuel consumption standards and greenhouse gas emission (GHG) standards limiting carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have created a new challenge for engine and vehicle manufacturers; maintain low NO_X, PM and other regulated emissions while reducing fuel consumption which have historically

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speaking opposed each other. These laws have forced manufacturers to continually innovate and look to new strategies and technologies to meet current and future regulations.

Nomenclature

CAC	Charge Air Cooling
CAFEE	Center for Alternative Fuels Engines and Emissions
CH_4	Methane
CI	Compression Ignition
CN	Cetane Number
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
EGR	Exhaust Gas Recirculation
GHG	Greenhouse Gas
HC	Hydrocarbon
HD	Heavy-Duty
L	Liter
LD	Light-Duty
LNT	Lean NO_X Traps
MD	Medium-Duty
N_2O	Nitrous Oxide
NO_X	Oxides of Nitrogen
ON	Octane Number
PM	Particulate Matter
RCCI	Reactivity Controlled Compression Ignition
SCR	Selective Catalytic Reduction
WHR	Waste Heat Recovery
WVU	West Virginia University

2. Compression Ignition Emission Standards and Current Compliance Solutions

NO_X and PM were arguably the most challenging regulated emissions to control for CI engines prior to GHG emissions standards. Since 1990, emissions standards for NO_X and PM from medium-duty (MD) and heavy-duty (HD) diesel engines have decreased by approximately 97 and 98 percent, respectively [1]. Until the implementation of the current PM and NO_X standards for MD and HD engines, which were phased in from 2007