Alexandria Engineering Journal (2016) xxx, xxx–xxx

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Alexandria Engineering Journal

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REVIEW

# The role of water-in-diesel emulsion and its additives on diesel engine performance and emission levels: A retrospective review

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Received 8 March 2016; revised 21 May 2016; accepted 19 July 2016

**KEYWORDS**

Combustion characteristics;
Emission characteristics;
Emulsion fuel stability;
Nano-particles;
Performance parameter;
Water-in-diesel emulsion fuel

**Abstract** Air pollution caused by the diesel engines has shown much interest in the domain of eco-friendly diesel fuels since enhanced environmental and human health are of concern. In order to obtain the efficient energy development with less polluted environment with existing diesel engines, continuous efforts have gone into research and development of water-in-diesel (W/D) emulsion fuels, which have the potential to reduce nitric oxides ($NO_x$) and particulate matter (PM) emissions simultaneously with improved performance level. The current discussion addresses the principle of W/D emulsion fuel, emulsion fuel stability, physico-chemical properties and effect of W/D emulsion fuel on combustion, performance and emission characteristics. In addition, role of nano-additives in W/D emulsion fuel, nano-fuel synthesis and its influence on engine performance and emission characteristics are also discussed. The survey of earlier reports led to the decision that the optimization of engine parameters, nano-particle size confirmation in nano-fuel and its handling from engine exhaust are the details to be studied in the domain of W/D emulsion fuel engine.


**Contents**



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Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2016.07.021


Please cite this article in press as: S. Vellaiyan, K.S. Amirthagadeswaran, The role of water-in-diesel emulsion and its additives on diesel engine performance and emission levels: A retrospective review, Alexandria Eng. J. (2016), http://dx.doi.org/10.1016/j.aej.2016.07.021

## 1. Introduction

Diesel engines are dominating in power generation and transportation sectors due their better efficiency and durability over gasoline engines. However, diesel engines are noted as major emission contributor to the environment, which is dangerous to human health. Hence, stringent regulations are to be followed to control the emission levels from diesel engines.

Low engine pollution has been promoted by adopting pre-formation and/or post formation emission control techniques such as the introduction of biodiesel, particulate filters, catalytic converters and W/D emulsion fuel. Out of these, W/D emulsion has been found to be the most economical solution that can be introduced in diesel engine without engine modification. Efficient combustion and better fuel economy are the added advantages of W/D emulsion fuel [1]. A decrease in temperature of the combustion products leads to a drop in $NO_x$ formation in diesel engines due to an endothermic reaction of water particles in W/D emulsion fuel during combustion. The presence of water also reduces the rate of formation of soot particles and enhances their burnout characteristics by increasing the concentration of oxidation species [2].

The use of W/D emulsion fuel in existing diesel engines is the active field of research for the past two decades. The incorporation of nano-particles in W/D emulsion fuel enhanced the combustion and emission characteristics. However, the complexity of analysing the combustion behaviour associated with micro-explosion, physical path of emulsion and soot formation leads to inconsistent reports in terms of SFC, BTE, CO and HC emissions. In addition, engine operating variables and ambient conditions also affect atomization and general combustion process and restrict drawing a general conclusion with W/D emulsion fuel. As a consequence, further research is needed to examine the combustion characteristics of W/D emulsion fuel under fluctuating conditions. This study addresses the basics and current status of W/D emulsion fuel, and enlightens the future intervention in the domain of W/D emulsion fuel.

## 2. Principle of water-in-diesel emulsion

Introduction of water in the diesel engine combustion zone was initially proposed by Prof. B. Hopkinson to improve the thermal efficiency, reduce the exhaust emissions and make better inter cooling of the gas engines [3]. There are generally three major approaches followed to introduce water in diesel engine: (i) direct injection into the combustion chamber through a normal injector [4], (ii) fumigating the water into the engine intake air [5] and (iii) in the form of emulsion [6]. The experimental investigation of all the above methods confirmed the advantages of water in diesel fuel and indicated the simultaneous reduction of NOx and PM emissions. Out of the above methods, diesel-water emulsion fuels appear to be the most appropriate since the desired emission characteristics can be obtained without engine retrofitting [7]. Besides, the micro-explosion of water particles during the combustion process helps to improve atomization and mixing of air-fuel mixture [8].

An emulsion consists of two incomplete immiscible liquids, with one of the liquid dispersed as small spherical droplets in the other [9]. The emulsion is generated by means of a high-energy emulsification method in the presence of surface-active agents (or) surfactants. These high-energy methods include mechanical agitation, high-pressure homogenizers, ultrasonic and supersonic vibrations [10]. As far as the smoke and NOx emissions are concerned, ultrasonic and supersonic vibrations have negative impact compared to emulsions prepared by mechanical homogenization [11].

### 2.1. Role of surfactants

In general, emulsion fuels are thermodynamically unstable systems. Over a period, emulsion fuels are slowly separated into two immiscible phases. The most common processes of an emulsion fuel destabilization are droplet-droplet coalescence, flocculation and creaming [12]. To form a kinetically stable emulsion fuel, the surfactants are used to lower the surface tension between water and diesel molecules.

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