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A comprehensive review on the application of emulsions as an alternative fuel for diesel engines

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ABSTRACT

Diesel engine is one of the most efficient and reliable energy conversion devices available till date. During the beginning of twentieth century, the plenty of low cost diesel have engrossed people to run diesel engines with diesel. However, after more than a century, the scenario has just been reversed. The frantic use of diesel has now led to a situation where the global fossil diesel storage may last merely for a few decades. As a result, the price of diesel has reached to a momentous height. This is coupled with the serious environmental pollution created by its burning. These facts have stimulated researchers around the globe to search for suitable, sustainable, renewable, and cheap alternative to diesel fuel, which is environmentally benign too. Among many solutions proposed, emulsified fuel is one of them, which comes under the fuel modification techniques. In this method, two or more mutually immiscible fluids are mixed together, which is expected to run a diesel engine and replicate its performance, combustion and emission characteristics. The most explored emulsified fuel in a diesel engine is the water in diesel emulsion. Alongside, the emulsions prepared with animal fat, methanol, ethanol and few studies with emulsified biodiesels have also been reported. The present paper attempts to accumulate most of these studies under a single shed. Efforts have been made to analyze the numerous studies on emulsified fuel both qualitatively and quantitatively. The paper starts giving an introduction to the types of emulsion, their characteristics, and the criteria of preparing an effective emulsion, followed by the review of their performance, combustion, emission and spray characteristics when run in a diesel engine. At the end, some of the significant points have been addressed based on the extensive review on the state-of-the-art literature, followed by some possibilities of future research.

Contents

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1. Introduction

1.1. Motivation

Diesel engines, at present, are used in a variety of applications, such as, power generation, transportation, agriculture, offshore drilling, military, marine, telecommunication generator sets, and elsewhere [1–3]. These are the building blocks of a nation's economy, especially for the developing countries, viz., India. This is attributed to its fundamental advantages in the form of high torque, turbocharging capability, high efficiency, and lower maintenance [1,3]. However, as the use of diesel engine is increasing, the stock of diesel is diminishing vary rapidly, with a continuous increase in harmful pollution. These include oxides of nitrogen (NO_X), oxides of carbon (CO and CO_2), oxides of sulfur (SO_X), hydrocarbon (HC), smoke, etc. [3]. The higher NO_X emission is credited by the high combustion temperature, at which nascent oxygen and nitrogen react together to form NO, the primary constituent of NO_X [1]. Hence, researchers around the globe are trying several options to reduce peak combustion temperature without declining engine performance to cut NO_X. However, the in-cylinder methods, adopted to reduce NO_X, again increase smoke. For example, exhaust gas recirculation (EGR) can reduce NO_X emission but increases particulate emission [4,5]. On the other hand, oxygen enrichment does the reverse. Moreover, when these two methods are employed together, they increase the cost, maintenance, and added energy ingestion. A rather diffident method, therefore, has to be established to reduce both of these emissions. Emulsification of fuel may be one of the methods, which can potentially solve this problem for long term. This technique enhances fuel efficiency and reduces emission of hazardous pollutants from diesel engines [5].

In emulsification, two or more immiscible fluids are mixed together such as water and diesel. The emulsions are thermodynamically stable, isotropic liquid mixtures of polar and non-polar fluids. This emulsified fluid (viz. water-in-diesel) when sprayed through a nozzle is atomized into fine liquid droplets. Since the boiling point of water is lower than that of diesel fuel, water droplets reach their boiling point first, once it has absorbed sufficient reaction heat. The vaporization phenomenon of water then disintegrates the oil layer and thereby forms smaller oil droplets which results in an increase of the oil's surface to volume ratio. This phenomenon is called “micro-explosion” [3,6]. A schematic diagram of micro-explosion is depicted in Fig. 1. The contact surface between the atomized oil droplets and air next to it, followed by their mixing extent are increased due to micro-explosion. This leads to a significant increase in the burning rate and burning efficiency. Besides, as reported by Abu-Zaid [7], the spontaneous burst of the fine water droplets form high-pressure steam and applies additional pressure on the piston top. Therefore, the engine torque enhances and performance improves [7].

1.2. Objective

The diesel engine emission can be reduced by using a number of ways. These are engine design improvement, improving fuel efficiency and lubricant quality, exhaust gas after-treatment or by

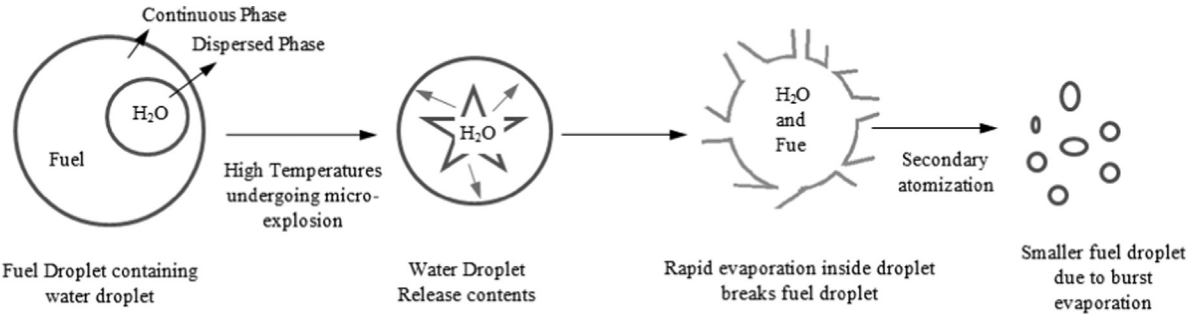

Fig. 1. Secondary atomization or micro-explosion [6].