Fuel 102 (2012) 41–48

Contents lists available at SciVerse ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Statistical corrosion evaluation of nozzles used in diesel CRI systems ☆

R.A. Taflan [a], M.I. Karamangil [b,*]

[a] Robert Bosch GmbH, Diesel Systems, Product Development Department, TR-16159 Bursa, Turkey
[b] Department of Mechanical Engineering, Faculty of Engineering and Architecture, Uludag University, TR-16059 Bursa, Turkey

HIGHLIGHTS

- ▶ Corrosion densities at these ten different areas of the injector were investigated.
- ▶ The most critical area of the nozzle is the nozzle stem.
- ▶ Corrosion density decreases with new generations of CRIN and CRIP nozzles.
- ▶ Corrosion level increases with increases in sulfur content in diesel.
- ▶ Biodiesel is more corrosive fuel than diesel.

ARTICLE INFO

Article history:
Received 2 October 2009
Received in revised form 17 February 2012
Accepted 7 June 2012
Available online 3 July 2012

Keywords:
Corrosion
Diesel injector
Nozzle

ABSTRACT

At present, diesel injection systems are desirable due to their advanced technology and balance between performance and consumption. However, there are still some problems that this technology is not yet able to overcome. One of these is corrosion. In the Common Rail Injection (CRI) system, one important component subject to corrosion attack is the nozzle. This part of the injector is the only component that is directly subject to high thermal load and chemical or electrochemical reactions with its surroundings in the combustion chamber. However, the main task of the injector nozzle is to properly inject high-pressure fuel into the combustion chamber while withstanding outside effects such as high temperature, high pressure, cavitation, and corrosion, among others. The aim of this study is to investigate the corrosion behaviors of nozzles with different runtimes, temperatures, and fuel types. In addition, corrosion behaviors are investigated on different sides of the nozzle. As a result, the relationships between corrosion and runtime, temperature, and different fuel types are described. All interpretations are derived from statistical results based on the experimental data.

1. Introduction

Corrosion is the primary method by which metals deteriorate. Most metals corrode on contact with water (and moisture in the air), acids, bases, salts, oils, aggressive metal polishes, and other solid and liquid chemicals. Metals will also corrode when exposed to gaseous materials such as acid vapors, formaldehyde gas, ammonia gas, and sulfur-containing gases. Corrosion specifically refers to any process involving the deterioration or degradation of metal components. Corrosion processes are usually electrochemical in nature, and the best known case is that of rusting of steel.

Corrosion is influenced by the properties of both the metal or alloy and the environment. The environmental variables that affect corrosion include the pH (acidity), free water content, and sulfur content of the fuel, oxidizing power (potential), temperature (heat transfer), velocity (fluid flow), and concentration (solution constituents).

Quigley and Barbour [1] describe a study used to assess the impact of rapeseed methyl ester (RME) fuel on performance parameters such as injector fouling, corrosion, water separation and fuel foaming tendency. The effect on RME quality of treatment with multifunctional diesel fuel additives (containing dispersant, demulsifier, anti-foamant and anti-corrosion components) was also investigated and shown to provide significant improvements to the base properties of fuels. From the laboratory tests conducted by Ohkawa et al. [2], it was made clear that all vegetable hydraulic oils show poor oxidation stability, and two vegetable hydraulic oils show strong corrosion to bronze materials. Three vegetable hydraulic oils containing 0.7%, 0.25% and 0% sulfur have been tested with a high-pressure axial piston pump. The 0.7% S vegetable hydraulic oil resulted in a rapid viscosity increase and serious bronze corrosion in the 32 MPa × 95 mDC pump test. The 0.25% S

☆ This paper is edited by American Journal Experts (AJE).

* Corresponding author. Tel.: +90 224 2941978; fax: +90 224 2941903.
E-mail addresses: Asim.Taflan@tr.bosch.com (R.A. Taflan), ihsan@uludag.edu.tr (M.I. Karamangil).

0016-2361/$ - see front matter Crown Copyright © 2012 Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.fuel.2012.06.037

vegetable hydraulic oil also caused light corrosion, while the 0% S vegetable hydraulic oil did not cause corrosion. Labeckas and Slavinskasthe [3] tested rapeseed oil, which includes many complicated long-side chain fatty acids and a 2.7-fold greater amount of water, which significantly increases its density and viscosity, reduces the cetane number, and stimulates acidity and corrosion activity. Winfried et al. [4] determined that non-esterified free fatty acids and different types of salts (Ca^{2+}, N^{+}, K^{+}) can cause corrosion in an engine and catalyze oxidation processes. The corrosion behaviors of biodiesels produced from various non-edible oils were estimated during a long-duration static immersion test by Kaul et al. [5]. Biodiesel from Mahua and Karanja showed no corrosion on piston metal and the piston liner, whereas Salvadora biodiesel had a marked corrosion effect on both metals due to high sulfur compound levels (sulfur content of 1600 ppm). In his paper, Yusuf [6] mentions the corrosion effects of sulfur compounds in diesel fuel. Caroa et al. [7] showed that corrosive effects of the biofuel component of biofuel/fuel oil mixtures necessitate the use of resistant materials in systems designed to store, transport and utilize these fuels. Specifically any copper and/or brass containing components must be replaced with steel. Grey cast iron showed slight corrosion and is better avoided when designing systems that utilize these biofuels.

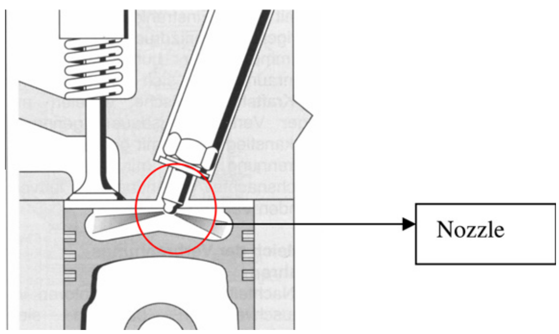

Fig. 1. Nozzle location in engine.

Fuel contaminated with water can cause engine corrosion or may cause a reversion of fatty acid methyl esters to fatty acids, which can lead to filter plugging. Therefore, EN 14214 imposed a maximum content of 500 $\mu g\, g^{-1}$ of water in biodiesel. In a study conducted in Greece by Schinas et al. [8], the produced methyl ester was routinely dried over anhydrous sodium sulfate. This technique proved to be efficient enough, and the water content of pumpkin methyl ester was below the specification limits. The effect of a water-soluble corrosion inhibitor on the growth of bacteria and its corrosion inhibition efficiency were investigated by Muthukumar et al. [9]. The main finding of this paper was that the water-soluble corrosion inhibitor is consumed by microbial action, which contributes to a decrease in inhibitor efficiency. Lundberg [10] points that in cold climates, careful attention should be paid to the materials of the fuel system. Large temperature variations may cause problems with water, including corrosion. These can be avoided to some extent by the use of additives and careful handling of the fuels.

The combustion of ethanol in compression ignition engines reveals some attractive properties of this fuel, e.g., low black smoke, NO/dx, and hydrocarbon emissions. The direct use of ethanol in CI engines is enabled by ignition improvers, a variety of which have been discussed in terms of their effectiveness, working mechanisms, exhaust emissions, and economy. Vehicle tests over more than 1 million kilometers applied by Hardenberg and Schaefer

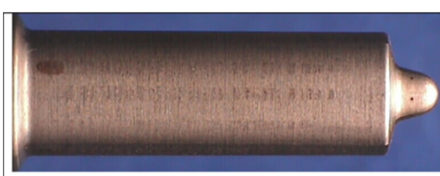	Level 0	No Corrosion
	Level 1	Slight Corrosion
	Level 2	Medium Corrosion
	Level 3	Remarkable Corrosion
	Level 4	Strong Corrosion

Fig. 2. Corrosion classification.