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Degradation of automotive materials in palm biodiesel

M.A. Fazal*, A.S.M.A. Haseeb, H.H. Masjuki

Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

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ABSTRACT

As compared to petroleum diesel, biodiesel is more corrosive for automotive materials. Studies on the characterization of corrosion products of fuel exposed automotive materials are scarce. Automotive fuel system and engine components are made from different ferrous and non-ferrous materials. The present study aims to investigate the corrosion products of different types of automotive materials such as copper, brass, aluminum and cast iron upon exposure to diesel and palm biodiesel. Changes in fuel properties due to exposure of different materials were also examined. Degradation of metal surface was characterized by digital camera, SEM/EDS and X-ray diffraction (XRD). Fuel properties were examined by measuring TAN (total acid number), density and viscosity. Among the metal investigated, copper is found to be least resistant in biodiesel and formed comparatively more corrosion products than other metals. Upon exposure of metals in biodiesel, TAN number crosses the limit given by standard while density and viscosity remain within the acceptable range of limit.

1. Introduction

Biodiesel is a sustainable alternative fuel which is rapidly getting more popularity in automobile section. It is produced from renewable sources [1] and has much potential to meet the concerns related to fossil fuel depletion and environmental degradation [1,2]. However, corrosion of automotive metals in biodiesel is one of the problems related to biodiesel compatibility issues. Studies on the corrosion of different automotive materials in diesel and biodiesel have been done by several researchers [3–5]. It becomes more corrosive during storage, transportation and utilization. It has been reported that biodiesel degrades through moisture absorption [6], oxidation [7,8] and other contaminations [9]. Haseeb et al. [4] observed that biodiesel is more corrosive for copper and bronze materials as compared to diesel. Geller et al. [3] reported that as compared to ferrous alloys, copper alloys are more prone to corrosion in fat based biodiesel. Pitting corrosion was found in bronze sintered nozzle after 10 h operation with biodiesel at 70 °C [5].

The existing data shows that biodiesel is more corrosive than diesel. Upon exposure of metals in biodiesel, the composition of biodiesel is also changed. However, such studies do not provide any information related to characterization of corrosion products on different metal surfaces upon exposure to biodiesel. Detection of corrosion products is important to understand the degradation mechanism of materials in biodiesel. In our recent study [10], we found that due to exposure of copper in palm biodiesel, the color of biodiesel was completely changed into green. The copper surface was subjected to pit corrosion but the presence of corrosion products on the biodiesel exposed copper surface was not visible. That study [10] was conducted by immersing copper in palm biodiesel at 80 °C for 1200 h under 250 rpm stirring speed. It was suspected that subsequent formation and dissolution of copper compounds which were mostly green in color could be attributed to change the color of biodiesel from colorless to green. Another study [4], which was conducted by static immersion test at room temperature, showed the presence of green copper compounds on biodiesel exposed copper surface. However, that study [4] was not devoted to characterise the corrosion products. Upon exposure to palm biodiesel at room temperature, the present study aims to investigate degradation mechanism of different automotive materials such as copper, brass, aluminium and cast iron by characterising the corrosion products. Under such condition, comparative corrosion rate for different metals and the change in fuel properties will also be investigated.

2. Materials and experiments

Palm biodiesel used in this work was supplied by Weshchem Technology Sdn Bhd, Malaysia. The analysis report provided by the supplier is summarized elsewhere [4]. Corrosion of copper (99.9%, commercially pure), brass (Cu: 58.5%, Zn: 41.5%), aluminum (99%,

* Corresponding author. Tel.: +60 3 79674448; fax: +60 3 79675317.
E-mail addresses: fazal@um.edu.my (M.A. Fazal), haseeb@um.edu.my (A.S.M.A. Haseeb), masjuki@um.edu.my (H.H. Masjuki).

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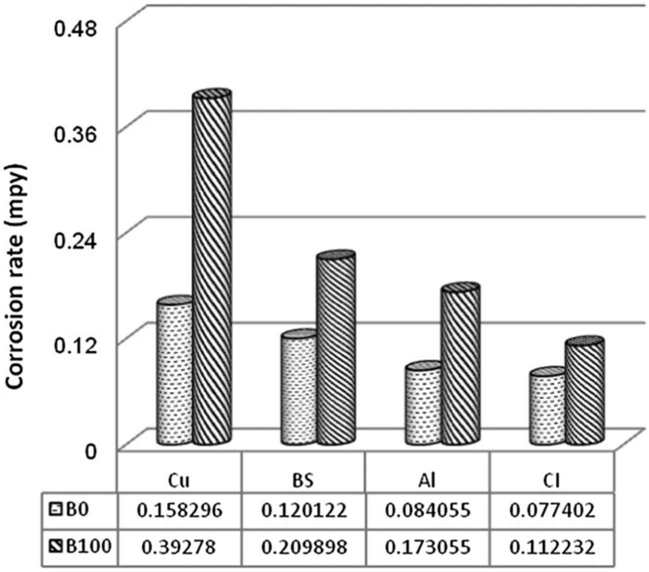

Fig. 1. Corrosion rate of copper (Cu), brass (BS), aluminum (Al) and cast iron (CI) after immersion in diesel (B0) and biodiesel (B100) at room temperature for 2880 h.

commercially pure) and cast iron (C: 3%, Si: 1.84%, Mn: 0.82%, P: 0.098%, S: 0.089%, Fe: balance) in palm biodiesel (B100) and petroleum diesel (B0) was investigated at room temperature (25–27 °C) for 2880 h.

The test coupons of copper (22.2 mm diameter × 2 mm thickness), brass (25.4 mm diameter × 2 mm thickness), aluminium (22.6 mm diameter × 2 mm thickness) and cast iron (36 mm diameter × 2 mm thickness) were prepared from respective round bars by machining and grinding. For hanging the specimen into fuels, a hole of diameter 2 mm was drilled near the edge of the specimen. Before immersion, the coupons were treated as follows: polished with silicon carbide abrasive papers (from grade 400–1200), then washed and degreased with acetone, rinsed with deionised water and finally immersed into test solution B100 and B0. After exposure, for removing corrosion products, samples were scrubbed lightly in a stream of water with a polymer brush so as not to mechanically abrade the original surface. Before and after immersion, weight of each coupon was measured by a balance with four decimal accuracy. Two duplicate coupons were immersed in each test fuel. Used glass-beakers (600 mL each) contained 400 mL fuel and were partly covered by the watch glass during the immersion period. At the end of the test, degradation of metals was investigated by measurement of corrosion rate and changes in surface morphology. The obtained data from weight loss was converted into corrosion rate (mpy) using the equation (1) [11].

$$\text{Corrosion rate(mpy)} = \frac{w \times 534}{D \times t \times A} \quad (1)$$

Where corrosion rate "mpy" stands for mils (0.001 inch) per year, w is the weight loss (mg), D is the density (g/cm^3), A is the exposed surface area (square inch) and t is the exposure time (h).

Changes in surface morphology were investigated by HITACHI S-3400N scanning electron microscopy connected with energy dispersive X-ray analysis (SEM/EDS). Corrosion products on biodiesel exposed metal surface were examined by using X-ray diffraction (XRD). The XRD patterns of the corroded samples were recorded using a diffractometer with a Cu K_α radiation of wavelength of 1.5406 Å operated at 40 kV/40 mA. The samples were step-scanned in the 2θ range of 5° with a step size of 0.01 and a time step of 3s. On the other hand, changes in fuel properties were investigated by measuring TAN (total acid number) number, viscosity and density according to ASTM (American society for testing and materials) standard D664, European standard EN14214 and ASTM (D6751 and D975) respectively.

3. Results

3.1. Comparision of corrosion for different metals

Fig. 1 shows the corrosion rate of copper (Cu), brass (BS), aluminum (Al) and cast iron (CI) in diesel and palm biodiesel after

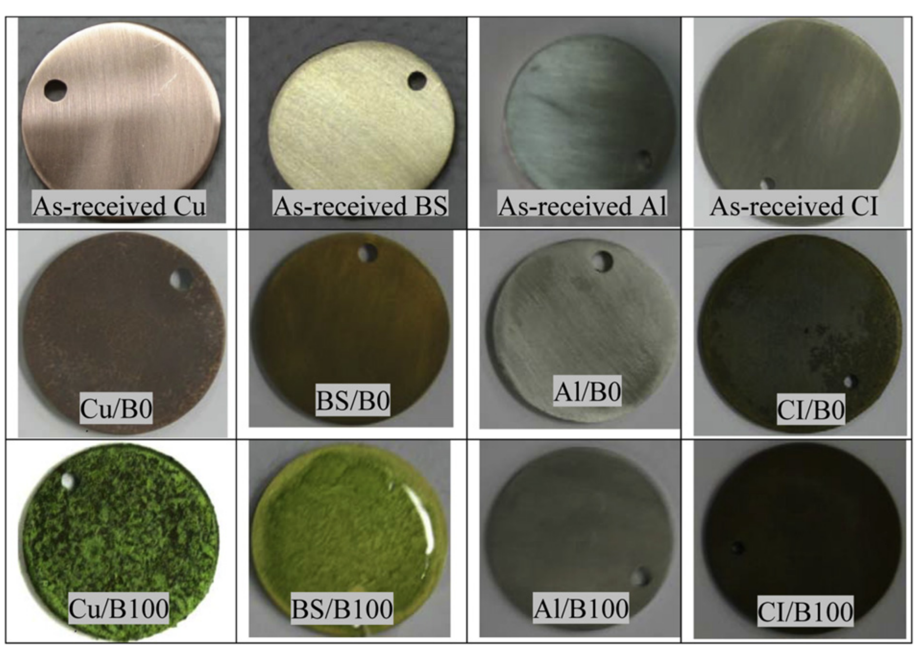

Fig. 2. Photographs of copper (Cu), brass (BS), aluminum (Al) and cast iron (CI) surfaces before and after exposure in diesel (B0) and palm biodiesel (B100) at room temperature for 2880 h.