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Research Article

A Comparison of Corrosion Behavior of Copper and Its Alloy in *Pongamia pinnata* Oil at Different Conditions

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Vegetable oils are promising substitutes for petrodiesel as they can be produced from numerous oil seed crops that can be cultivated anywhere and have high energy contents, exhibiting clean combustion behavior with zero CO_2 emission and negligible SO_2 generation. The impact of biofuel on the corrosion of various industrial metals is a challenge for using biofuel as automotive fuel. Fuel comes in contact with a wide variety of metallic materials under different temperatures, velocities, and loads thereby causing corrosion during storage and flow of fuel. Hence, the present investigation compares the corrosion rates of copper and brass in *Pongamia pinnata* oil (O100), 3% NaCl, and oil blend with NaCl (O99) obtained by static immersion test and using rotating cage. The corrosivity and conductivity of the test media are positively correlated. This study suggested that the corrosivity of copper is higher than brass in *Pongamia pinnata* oil (PO).

1. Introduction

The rate of petroleum reserve discovery is declining while energy demand keeps increasing. The current expansion of the Indian economy has escalated petroleum demand, prices have surged, hurting the economies of poor and developing countries. In order to improve the economic status, the renewable, nontoxic biofuel comes with many advantages for the environment. Vegetable oils represent a ready, renewable, and clean energy source that has shown promise as a substitute to petroleum diesel for diesel engines. Edible oils like soybean, rapeseed, sunflower, and palm oil are being used for the production of biodiesel [1] and have a very high value and market demand as food product causing food shortages and price increase especially in developing countries [2]. To overcome this situation, researchers are looking for nonedible oil plants. *Pongamia pinnata* [3, 4], *Jatropha curcas* [5, 6], and other trees native to humid and subtropical environments can be grown on degraded and marginal land.

Based on the biodiesel handling and guidelines report, copper, brass, bronze, lead, tin, and zinc are found to be corroded by biodiesel. Corrosive characteristics of biofuel are important for long-term durability of storage tanks and pipelines. Metal contaminants can trigger undesirable reactions leading to the instability and degradation of biofuel. Currently used indicators of corrosiveness, namely, copper strip corrosion and TAN value as prescribed by ASTM standards, are not effective enough [7]. Corrosive nature of biofuel under wide spectrum of compositional and operating variables should be investigated to obtain enough scientific data for confident use of biofuels. Hence, in the present paper corrosion studies of copper and brass in PO were performed by mass loss method in static and flow conditions.

2. Materials and Methods

2.1. Selection of Metal. Based on the review, it can be said that copper and copper alloys are more prone to corrosion in biofuels as compared with ferrous alloys [8]. Hence, the corrosion behavior of copper and brass in *Pongamia pinnata* oil has been studied.

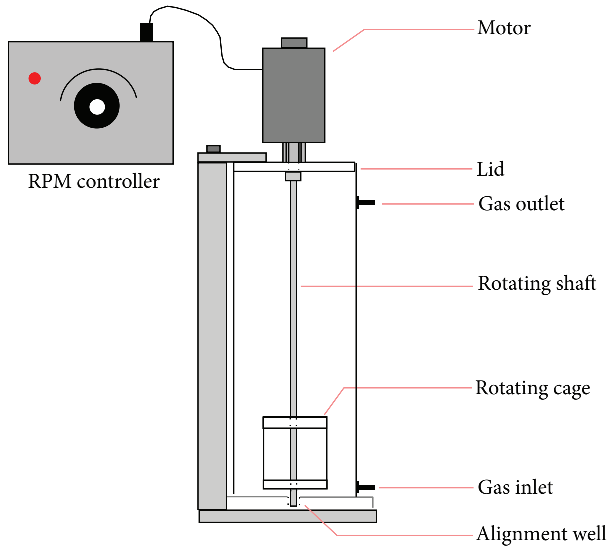

Figure 1: Schematic diagram of rotating cage.

Table 1: Chemical composition of the materials.

Element	% Composition	
	Copper	Brass
Zn	2.90	39.6
Al	<.010	<.010
Sn	0.038	0.011
Pb	<.001	<.001
Si	0.011	0.004
Ni	<.010	0.010
Fe	0.110	0.037
Mn	<.002	<.002
P	0.003	<.001
S	0.043	<.005
Bi	<.001	<.001
Sb	<.005	0.011
As	0.002	<.001
Co	<.010	<.010
Ag	0.002	—
Mg	0.001	—
Cu	96.89	60.32

2.2. Preparation of Metal Sample. Commercially available metal sheets were machined into coupons of an area of 33.9 cm^2. Holes were drilled on the center of the coupons for static immersion test. The cleaning procedure was carried out as per ASTM G1. The panels were stored in a desiccator before use. The chemical compositions of the materials are presented in Table 1.

2.3. Selection of Biofuel and Characterization. Pongamia pinnata oil was collected from Bannari Amman sugars Ltd., India, and the analyzed properties of the oil are given in Table 2.

Table 2: Characterization of *Pongamia Pinnata* oil as per ASTM D6751.

Parameters	Value	Unit
Flash point	124.0	°C
Water and sediment	0.0269	% vol
Kinematic viscosity (at 40°C)	15.10	mm^2/sec
Sulfated ash	0.01	% mass
Sulfur (S 15 grade)	0.0007	ppm
Sulfur (S 500 grade)	0.012	ppm
Copper strip corrosion	2	—
Cetane	60.12	—
Carbon residue	0.019	% mass
Acid number	0.02	mg KOH/gm
Free glycerin	0.01	% mass
Total glycerin	0.12	% mass
Phosphorus content	0.000496	% mass
Distillation temperature, atmospheric equivalent temperature, 90% recovered	236	°C

2.4. Mass Loss Method

2.4.1. Static Immersion Test. Specimens were weighed and immersed in 200 mL of oil (O100), oil and 1% of 3% NaCl solution (O99), and 3% NaCl solution, respectively, for a period of 100 h. Specimens were removed after the set intervals of time and wiped with trichloroethylene for the removal of the excess oil. They were cleaned and reweighed. The loss in mass was determined, and average results from three specimens are reported. The formula to calculate the corrosion rate is given elsewhere [9].

2.4.2. Rotating Cage. Rotating cage is a promising and reliable method to simulate pipeline flow under laboratory conditions to evaluate the corrosion rate of the metals [10].

Figure 1 shows a schematic diagram of rotating cage, which has been fabricated as per ASTM G184. The acrylic vessel was filled with 4 litres of the test solution. The metal samples were held between two Teflon holders, which have been designed to hold eight coupons. Experiments were conducted for a period of 100 h at the rotation speed of 500 rpm. The rate of corrosion was calculated from the difference in mass of the coupons.

2.4.3. Conductivity Measurement. The conductivity of O100, O99, and 3% NaCl was measured using a conductivity meter (EQUIPTRONICS model no. EQ-660A) before and after exposure of coupons in the test media for static and flow conditions.

3. Results and Discussion

Biofuel contains different types and amounts of unsaturated and saturated fatty acids. Unsaturated fatty acids with double bonds in their structures are more susceptible to oxidation.

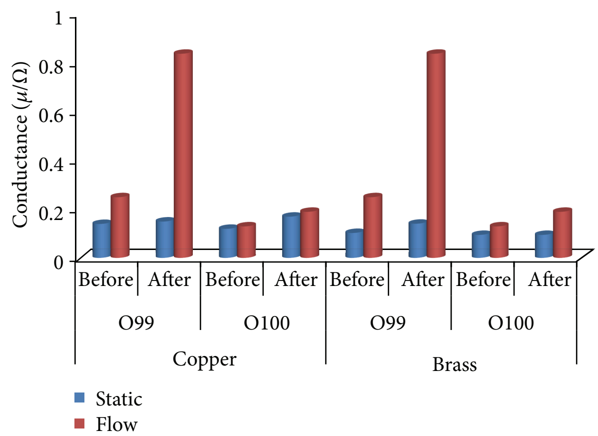

Figure 2: Conductivity of PO exposed to copper and brass at different conditions.

This oxidation may be facilitated by the metals and significantly increase the sediment formation in biofuel. Fuel degradation due to metal contact may be differing from metal to metal. Corrosivity of *Pongamia pinnata* oil is due to the presence of fatty acids. Oleic acid (51.59%) is one of the major components which are responsible for corrosion [11].

3.1. Corrosion Rates. The corrosion rates obtained for copper and brass in static and flow conditions in NaCl, O99, and O100 as determined by mass loss method are presented in Table 3. The observed corrosion rates in PO for copper by static immersion test and at the rotation speed of 500 rpm are 0.219 and 2.704 mpy, respectively. Higher corrosion in the latter case may be attributed to the presence of relative motion between metal and the fuels [12]. The corrosion was severe in NaCl and the least in O100 which can be justified from the fact that the corrosion rate increases with the increase in the vortex length [13]. The measured vortex lengths for NaCl and O100 are 13.2 and 2.5 cm, respectively. On addition of 1% NaCl solution, the corrosion rate increased to a small extent when compared to O100 in both conditions. The lower corrosion rate of O100 may be due to the nonionic nature of the fuel, and it has a strong affinity to be in contact with the metal. Similar trend was found in the case of brass, and it should be noted that brass is less corrosive than copper. As evident from Table 1, brass is an alloy, mainly composed of copper and zinc. In general, brass has more gold-like coloring and is even more corrosion resistant than copper.

3.2. Conductivity Measurement. The conductivities of various solutions, before and after exposure of metal coupons in both the conditions, are depicted in the Figure 2. NaCl has the highest conductance while PO has the least. The addition of 1% NaCl has not increased much the conductivity. This brings out the direct correlation of noncorrosive nature of oil with the conductivity. However the conductance of solution after exposure was higher than that before, indicating that the ionic content increased due to corrosion of the metals.

Table 3: Mean corrosion rate of copper and brass by mass loss method.

Metal	Medium	Mean corrosion rate (mpy)	
		Static	Flow
Copper	NaCl	2.125 ± 0.166	9.608 ± 0.819
	O99	0.231 ± 0.017	3.573 ± 0.307
	O100	0.219 ± 0.054	2.704 ± 0.444
Brass	NaCl	0.527 ± 0.029	2.582 ± 0.318
	O99	0.228 ± 0.017	2.091 ± 0.152
	O100	0.201 ± 0.041	1.502 ± 0.407

4. Conclusions

(1) Under the experimental conditions studied, corrosion rates of copper in *Pongamia pinnata* oil are found to be higher than brass.

(2) The direct correlation of the corrosion rate with the conductivity was observed in this system.

(3) Higher corrosion rates of the metals were observed in rotating cage than in static immersion test.

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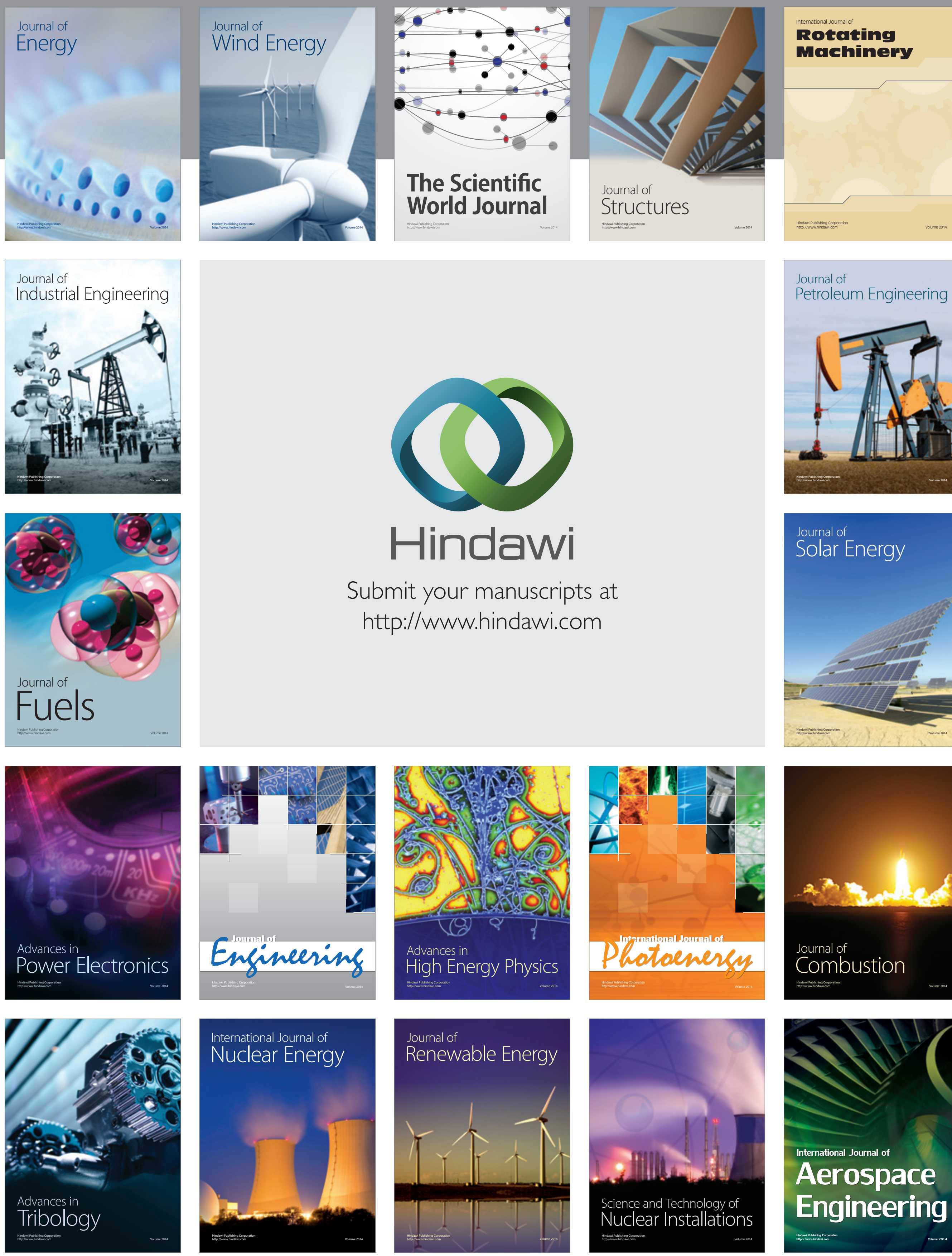
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