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Waste cooking oil blended with the engine oil for reduction of friction and wear on piston skirt

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HIGHLIGHTS

- Bio-lubricant viscosity increases and wear decrease as the concentration of WCO decrease.
- Dewatering process reduced water in WCO that can contribute to the corrosive engine.
- Coefficient of friction increased under 5% and 10% volume concentration of WCO.
- Speed, load, and volume composition effect on coefficient of friction and specific wear rate.
- Mild abrasion, pitting corrosion, and severe delamination of the specimen surface increased.

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ABSTRACT

Currently, development of recycling, renewable, and sustainable products to replace fossil fuel products is an essential matter for industrial profiteering as well as environment protection. In the present study, waste cooking oil blended with SAE10W-40 should reduce the wear and friction on the piston skirt. Wear and friction performance were evaluated using piston skirt-liner contact tester, and the piston material was aluminum 6061. The design of experiment (DOE) was constructed using the response surface methodology (RSM) technique. Influence of different operating parameters such as rotational speeds (200 RPM, 250 RPM, 300 RPM), volume concentration (5% and 10% of waste oil), and loads (2 kg, 5.5 kg, and 9 kg) were optimized. Based on the results of moisture content and viscosity; as the concentration of waste cooking oil increases, the viscosity of the lubricant decreases. The lowest moisture content was at the 5% volume concentration. The increase in the coefficient of friction occurred in 5% and 10% volume concentration of waste cooking oil for both pairs. The RSM model showed that the speed, load, and volume composition have a significant effect on the coefficient of friction (COF) and specific wear rate (WR). The optimum obtained for both output (COF and WR) were 0.0596μ for COF and 0.6827μ for WR. The relevant parameters such as speed, load, and volume composition are 200 rev/min, 9.0 kg and 0.7071% of volume concentration respectively. Afield emission scanning electron microscope (FESEM) analysis shows mild abrasion, pitting corrosion, and severe delamination of the specimen surface increased when running at higher load.

1. Introduction

The development of the new technologies solutions, such as introducing lightweight materials, less harmful fuels, controlled fuel combustion and more efficient gas after treatment are possible means to decrease environmental problems brought by vehicles and machines. Lubricant, fuel and engine materials are closely related to each other. The conventional mineral oil based lubricant was developed based on fossil fuel (such as gasoline and diesel fuels) which is not suitable for the biodiesel-fueled engine as it degrades lube oil quality and increases the wear rate of the engine components. There are various purposes of lubrication which are to reduce wear and increase cooling that result from the contact surfaces in motion and reduce the coefficient of friction between two contacting surfaces [1,2]. Other than that, the function of the lubricant is to prevent rust and reduce oxidation, to act as an insulator in transformer application and finally to act as a seal against

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Nomenclature

A_s	heat transfer surface area, m^2
C	specific heat capacity, J kg^{-1} K^{-1}
D	diameter of cooling channel, m
h	heat transfer coefficient, W m^{-2} K^{-1}
k	thermal conductivity, w m^{-2} K^{-1}
k_r	thermal conductivity ratio
m	mass, g
T	temperature, °C
V	volume, m^3

Greek letters

ϕ	volume concentration
φ	volume fraction, ϕ/100
ρ	density, kg m^{-3}
μ	micron
μ_r	dynamic viscosity ratio

Subscripts

b	bulk
bf	base fluid
eff	effective
eq	equation
r	ratio

Abbreviations

ASTM	American Society for Testing and Materials
SAE	Society of American Engineers
WR	Wear Rate
COF	Coefficient of Friction
DOE	Design of Experiments
RSM	Response Surface Methodology
SEM	Scanning Electron Microscope
EDX	Energy-Dispersive X-ray

dirt and dust and water. A lubricant is a substance that reduces friction and wear by providing a protective film between two moving surfaces. Lubrication occurs when a lubricant film separates two surfaces. Good lubricants have a high viscosity index (VI), thermal stability, high boiling point, low freezing point, corrosion prevention capability and high resistance to oxidation [1]. To reduce friction and wear, the engine tribology is required to achieve effective lubrication of all moving components, with minimum adverse impact on the environment as shown in Fig. 1. Improvement in the tribological performance of yields can lead to a reduction fuel consumption, increase engine power output, reduced oil/lubricant consumption, improved durability, reliability and engine life and reduced maintenance requirements and long service intervals.

The internal combustion engine and open flame combustion also a contributor to atmospheric pollution through hydrocarbon, particulate and NO_x (Nitrogen Oxide) emissions and to the greenhouse effect via carbon dioxide emissions [3–7]. According to Andersson [8], 12% of the available energy in the fuel is available to drive the wheels with some 15% being dissipated as mechanical, mainly frictional losses as shown in Fig. 2. Fitzsimons [9] showed that piston skirt accounts for 40% of piston-cylinder friction. Thus,

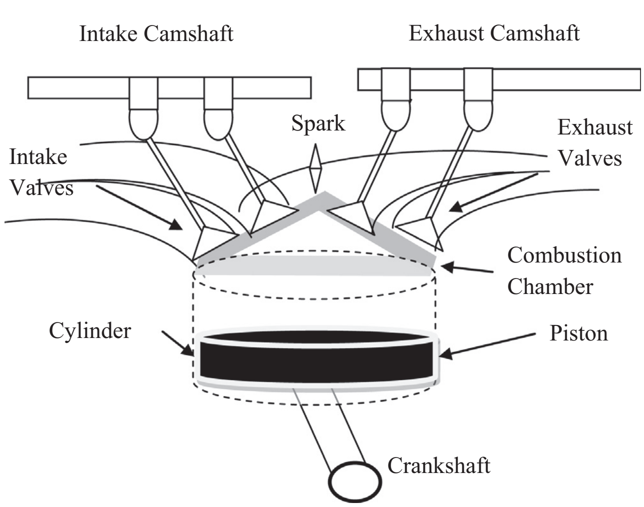

Fig. 1. Main engine components in internal combustion engine [3].

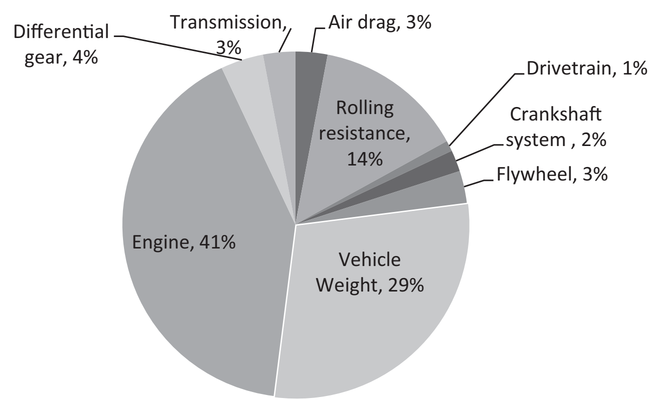

Fig. 2. Energy consumption developed in an engine [3].

piston skirt accounts for nearly 3% of fuel energy. Concerning energy consumption within the engine as shown in Fig. 2, the major portion (48%) of energy consumption developed in an engine, 35% portions are acceleration resistance and 17% is a cruising resistance. In the engine friction loss, sliding of the piston rings and piston skirt against the cylinder liner wall is the largest contribution to friction in the engine. The next most significant friction is rotating engine bearings, (crankshaft and camshaft journal bearings) followed by valve train (notably at the cam and follower interface) and the auxiliaries such as the oil pump, water pump, and alternator) [10]. The relative proportions of these losses and their total vary with engine types, component design, operating conditions, choice of engine lubricant and the service history of the vehicle for example worn condition of the components in the engine.Fig. 3

All part of the piston is the heart of the reciprocating internal combustion engine. The piston carries the ring pack, which essentially a series of metallic rings, which are the role is to maintain an effective gas seal between the combustion chamber and the crankcase [11]. Piston rings for internal combustion engine must meet all the requirement of a dynamic seal for axial (linear) and secondary motions (lateral and tilting)that operates under demanding thermal and chemical conditions [12]. The role of these motions in lubrication of piston skirt are clearly shown by Balakr-

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