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Full Paper

Assessment of lubricating oil degradation in small motorcycle engine fueled with gasohol

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Abstract: Assessment of the degradation of lubricating oil was performed on the lubricants which had been used in a small motorcycle engine fueled with gasohol in comparison with the lubricants from gasoline-run engine. The lubricant properties examined in the assessment were lubricating capacity, viscosity and stability to oxidation. Lubricating capacity was evaluated by accelerated wear test on the Timken tester. Lubricating oils from gasohol-run engine appeared to produce about 10% greater wear than that made in oils from gasoline-run engine. There was no significant difference between the effect of gasohol and gasoline on the viscosity of the used lubricating oils. Moreover, no oxidation products in any used oil samples could be detected.

Keywords: engine wear, lubrication, gasohol, lubricating oil degradation

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Introduction

Advanced lubricants have been formulated to reduce wear and friction of the tribological components of an engine by interposing a film of material between rubbing surfaces. Apart from lubrication, an engine oil also cleans and cools the engine, inhibits corrosion and improves sealing. The lubricant consists mainly of a base oil and chemical additives, which are blended according to its grade and specific duty. When adjusted optimally to its task, wear and maintenance requirements can be reduced leading to a greater saving and less problem with air pollution. During use, however, lubricating oil properties tend to degrade. Engine lubricant is degraded by heat, oxidation, and possible contamination from fuel and other materials. Any unburned fuel may leak from the engine combustion chamber into the lubricating oil sump, possibly via blow-by flow mechanism [1]. Contamination can degrade the performance of engine lubricants, thus affecting engine parts and properties. The extent of degradation depends on the severity of engine conditions and length of use. Used lubricating oil contaminated by dirt, fuel, water, metals, products of combustion, and other materials is therefore replaced on a regular basis in all operating equipment. Degradation of lubricating oils after various degrees of their use can be observed and studied by a number of analytical methods such as Fourier transform infrared (FTIR) spectroscopy [2-5], atomic absorption spectroscopy [5-6], and measurement of change in viscosity and acidity [7-10]. The information obtained is often used to predict useful lubricant service life.

Ethanol is a renewable fuel derived from domestic feedstock. It is considered as an important alternative fuel and extender for engines. In Thailand, gasohol, a blended mixture of 10% ethanol and 90% gasoline, has been used extensively as transport fuel for the past decade. Relatively few studies on the degradation of tribological performance of a lubricant in small gasohol-fueled engines have been reported in the literature. The aim of this study is therefore to investigate the lubricating oil degradation in a small motorcycle engine fueled with gasohol for a prolonged period. This is done in comparison with oil from the same type of engine which is run on regular gasoline by measuring changes in the lubricant's properties, viz. lubricating capacity, viscosity and stability to oxidation.

Materials and Methods

Lubricants

Two different types of engine oil, i.e. mineral- and synthetic-based oils, whose properties are shown in Table 1, were used in this study. Both oils are commercially available from local distributors.

Small engines

Four motorcycles of similar built and age were used to run four test combinations of fuels and lubricants in parallel: (i) gasoline and mineral-based oil; (ii) gasoline and synthetic-based oil; (iii) gasohol and mineral-based oil; and (iv) gasohol and synthetic-based oil. Their engines were of a Honda, four-stroke of the *Dream* series. It is a lightweight, rugged, simple-to-maintain, high-performance engine. Its specifications are given in Table 2. Prior to the test, all engines were flushed to make sure that no other oil was present to contaminate the test oil. Then they were filled with the new lubricant. Road tests were performed on these vehicles with both mineral- and synthetic-based oils for up to 3000 km, a recommended oil-change mileage. This amounted to the test duration of 4-6 months. At the mileage of 1500 km and 3000 km, samples of the lubricating oil from each engine were collected from the crankcase sump with a syringe for later analysis (with replenishment of fresh oil at 1500 km). After completion of the test, the engine components were inspected visually to assess the degree of wear and tear.

Wear machine

All samples of fresh and used lubricating oils from the road test were subjected to bench wear test. The accelerated wear test was carried out using a Timken universal wear and friction testing machine. Schematic diagrams of the machine and testing arrangement of the specimen are shown in Figure 1. The machine comprises a motor-driven, rotating axle which provides a relative motion to the loaded specimen, fully immersed in the lubricant to be tested. A test specimen was used to imitate solid metallic contact and simulate the lubricity effect of the oil at the contact. The load on the test specimen can be adjusted. The bench test conditions used were: load of 33 N, rotating speed of 500 rpm, and temperature of 25°C in accordance with ASTM standard [11]. The wear was generated under lubricated condition on the cylindrical steel specimen subjected to the rolling contact. The specimen was weighed using an electronic balance at a fixed time interval and wear scar area on the test specimen was monitored. Each test for each oil sample was done in triplicate and high repeatability (> 90%) was obtained.

Table 1. Specifications of engine lubricants

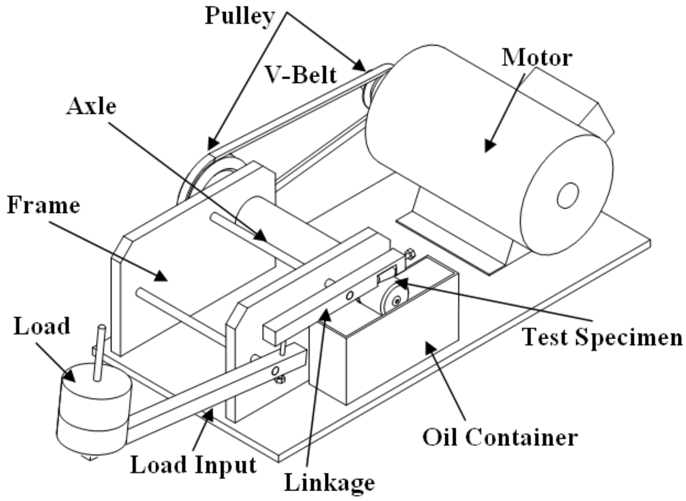
Property	Mineral-based oil	Synthetic-based oil
Grade	SAE 20W-50	SAE 5W-40
Kinematic viscosity at 100°C (cSt)	18.5	14.2
Viscosity index	128	176
Cold cranking simulator at -25°C (cP)	7800	5410
Flash point (°C)	246	227
Pour point (°C)	-21	-45
Colour	red	yellow

Table 2. Motorcycle engine specifications

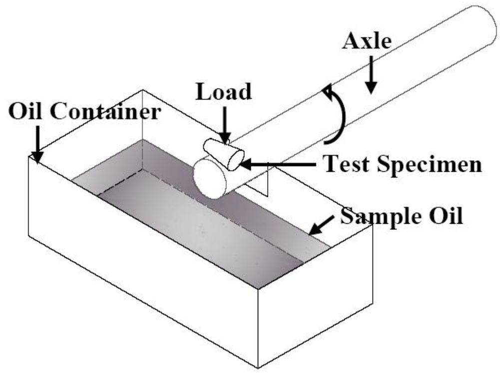
Engine	: Honda
Model	: Dream 125
Type	: 4-stroke, OHC
Combustion	: Direct injection, naturally aspirated
Number of cylinder	: 1
Bore	: 52.4 mm
Stroke	: 57.9 mm
Displacement	: 124.9 cc
Compression ratio	: 9.3:1
Ignition system	: CDI
Ignition timing	: 15° BTDC
Cooling system	: air cooled
Sump capacity	: 700 cc

Analysis methods

A viscometer was used to measure the viscosity of the tested lubricants according to ASTM standard [12]. Analysis of the lubricants was also performed by FTIR spectroscopy [13]. The method is based on the fact that specific functional groups absorb in unique regions of the infrared spectrum, thus allowing the identification of contaminants and oxidation products. Spectra were acquired on a Bruker FTIR Tensor 27 model. The resolution for the spectral data was 4 nm and the number of scans was set at 200. The wear surfaces generated on the cylindrical specimens subjected to rolling contact under lubricating condition in the Timken tester were examined with an optical microscope. Apparent areas of wear scar were measured.



(a)



(b)

Figure 1. (a) Timken universal wear machine; (b) Testing arrangement of the specimen

Results and Discussion

The motorcycles completed the road test without any performance problem. After completion of the test, their engines were disassembled and the deposit formations on the cylinder head, piston crown, piston rings, inlet and exhaust valves were examined. Visual inspection of components showed little change compared to their initial conditions. The engine components did not show any sign of wear and the critical components were in good working conditions, although their surfaces were observed to be covered with light deposits. Carbon residuals were also found on the piston ring and ring grove. Exhaust ports and valve stems were coated with thin deposits but they could be easily removed. It should be noted that erratic operation from deposit accumulation was not encountered. The formation of carbon deposits did not seem to affect the overall performance of the engine.

The sliding contact between metal components of any mechanical system is always accompanied by wear, which results in the generation of minute particles of metal [1]. In this study, however, when accelerated wear tests were performed on the Timken tester, wear rate in terms of mass loss was found to be insignificant. Wear scars on the test specimens were observed to be smooth. Their dimensions and areas (shown schematically in Figure 2) are summarised in Table 3. It can be seen that the wear scar area increases with increasing distance travelled for all cases. Mineral-based oil gives larger scar areas than those produced in synthetic oil. For the same type of engine oil, the one from gasohol-run engine appears to produce about 10% larger scar areas than those produced in oil from gasoline-run engine.

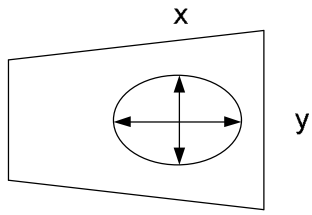


Figure 2. Wear scar of test specimen and its measurement

Table 3. Average dimensions and areas of wear scar from Timken test

Oil type	Fuel used	Distance travelled (km)	x (mm)	y (mm)	Area (mm^2)
Synthetic	Gasoline	0	3.73	6.57	76.95
		1500	4.69	6.58	96.90
		3000	4.93	8.09	125.23
	Gasohol	0	3.73	6.57	76.95
		1500	4.36	7.87	107.74
		3000	5.33	8.61	132.34
Mineral	Gasoline	0	4.69	7.41	95.16
		1500	4.75	7.58	110.26
		3000	4.97	8.22	128.28
	Gasohol	0	4.69	7.41	95.16
		1500	4.82	7.38	111.69
		3000	5.15	8.20	144.10

The lubricating property of an engine oil changes with running time due to effects of oxidation, thermal degradation, reaction with sliding surfaces, contamination by engine blow-by, and additive depletion [14]. In this investigation, the effects are shown in terms of kinematic viscosity and viscosity index of the lubricating oils (Figures 3-4). Oil viscosity has an effect on heat generation in bearings, gears, pistons and other engine components due to internal fluid friction. Formation of lubricating films and rate of oil consumption are also affected by viscosity. A proper level of viscosity is desired over a wide range of temperature. The viscosity index is used as a measure of response of an oil to temperature change. As seen from Figure 3, the viscosity of all oil samples decreases with operation time (measured as distance travelled), the viscosity changes being about 20% and 45% at 3000 km mileage for synthetic- and mineral-based oils respectively. This is contrary to the expectation that the viscosity is likely to increase due to loss of lighter fractions from evaporation or oxidation [15]. The corresponding changes in viscosity index (Figure 4) are smaller—about 10% and 20% for synthetic- and mineral-based oils respectively. Within the test conditions under study, however, there is no statistically significant difference between the effect of gasoline and gasohol on viscosity. Incidentally, when simulated lubricant contamination was carried out by adding gasohol at merely 1% by volume to the lubricant, the viscosity was found to drop by more than 20% for both types of oils.

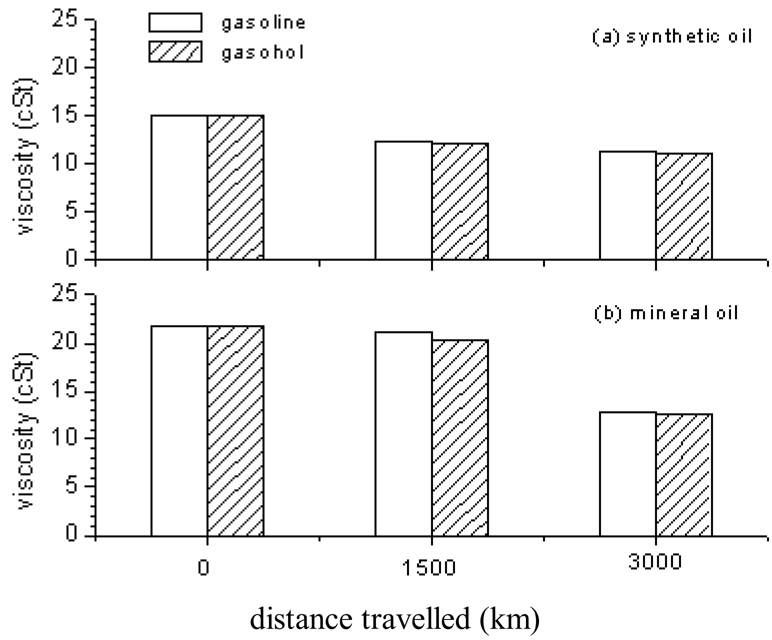


Figure 3. Change in kinematic viscosity of lubricating oils used in gasoline- and gasohol-fueled engines

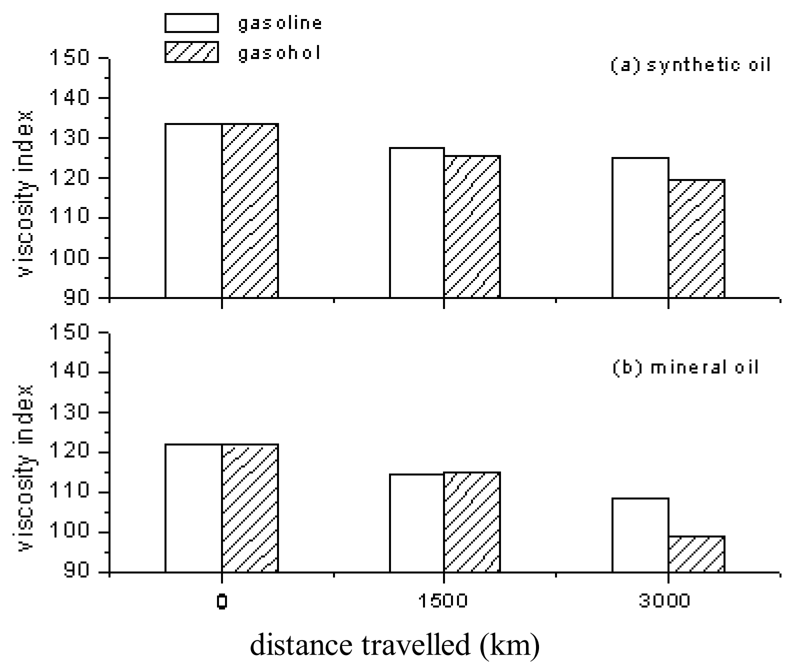


Figure 4. Change in viscosity index of lubricating oils used in gasoline- and gasohol-fueled engines

As oil is exposed to oxygen in air at elevated temperature oxidation reactions may take place during operation, which leads to the formation of oxygenated species including carboxylic acids, thus increasing the acidity of the oil and contributing to corrosion. IR spectroscopy may be used to identify the presence of these oxidation products. This is characterised by changes in the O-H, C=O and C-O spectral regions at 3600-2500, 1900-1600 and 1500-900 cm^{-1} respectively [2, 16]. Figure 5 shows the

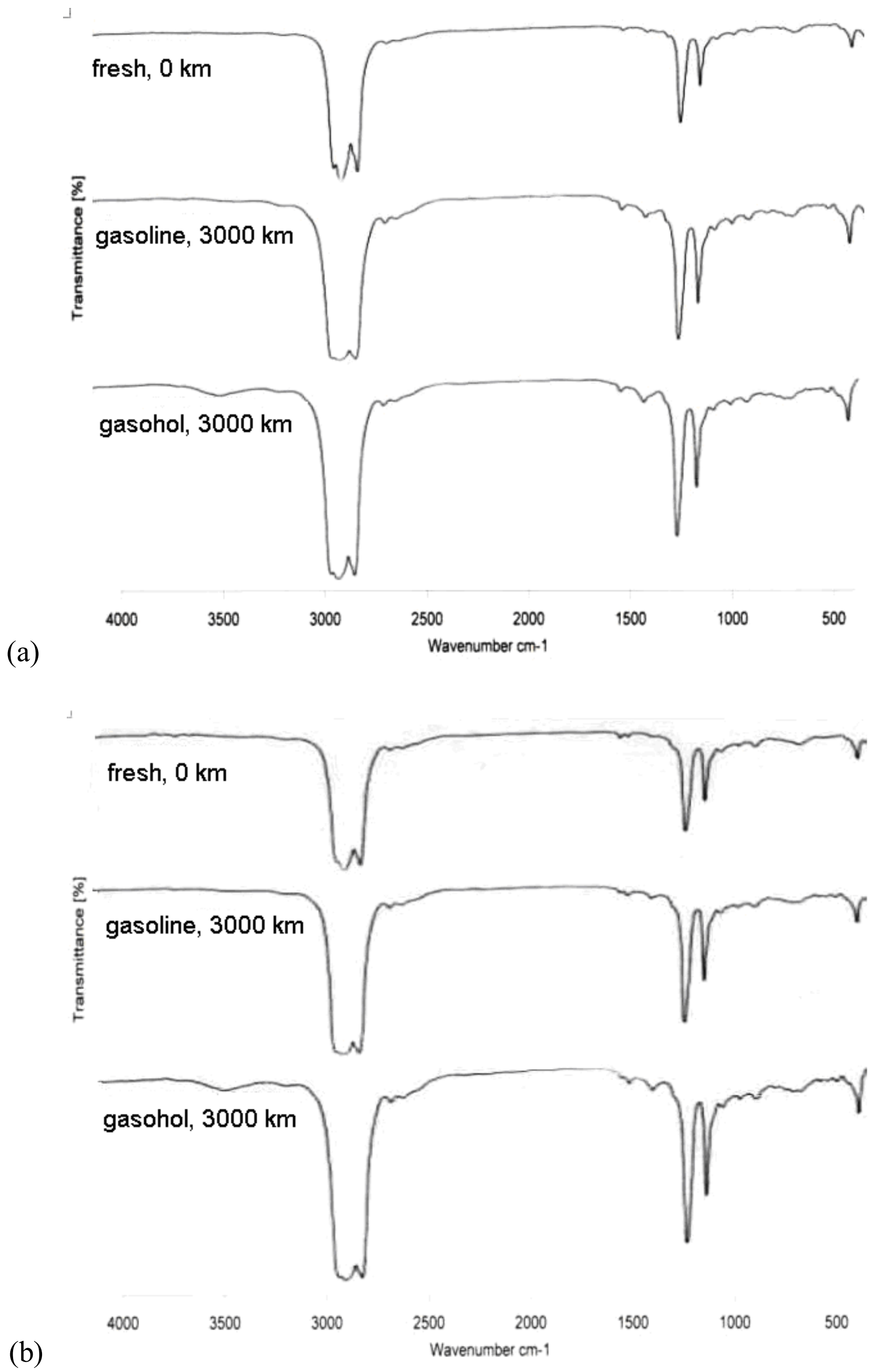


Figure 5. FTIR spectra of fresh and used lubricating oils: (a) synthetic; (b) mineral

spectra of fresh and used oils at the end of the road test. Very small changes are found in these three spectral regions, suggesting negligible formation of oxidation compounds in any of the oil samples. Confirmation of this finding is possible by employing such methods as cyclic fast neutron activation analysis and nuclear magnetic resonance spectroscopy [17].

Conclusions

From this investigation, there seems to be no significant difference between the effect of gasohol and that of gasoline on the lubricating oil performance and degradation in a small motorcycle engine under normal engine operation.

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