

Unique Needs of Motorcycle and Scooter Lubricants and Proposed Solutions for More Effective Performance Evaluation

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ABSTRACT

The operating conditions of a typical motorcycle are considerably different than those of a typical passenger car and thus require an oil capable of handling the unique demands. One primary difference, wet clutch lubrication, is already addressed by the current JASO four-stroke motorcycle engine oil specification (JASO T 903:2011). Another challenge for the oil is gear box lubrication, which may be addressed in part with the addition of a gear protection test in a future revision to the JASO specification. A third major difference between a motorcycle oil and passenger car oil is the more severe conditions an oil is subjected to within a motorcycle engine, due to higher temperatures, engine speeds and power densities.

Scooters, utilizing a transmission not lubricated by the crankcase oil, also place higher demands on an engine oil, once again due to higher temperatures, engine speeds and power densities. However, because scooter oils do not need to lubricate a wet clutch or protect gears, scooter oils can provide more fuel economy benefits than motorcycle oils, when properly formulated.

First, this study compares the piston deposit performance of motorcycle oils and passenger car oils in the API Sequence III Test and in a fired-engine motorcycle piston deposit evaluation. While the API Sequence III Test is certainly an effective tool for ensuring passenger car motor oil piston deposit performance, the results show that some oils formulated to meet the performance requirements of the Sequence III test do not match the performance of motorcycle-specific oils in a motorcycle piston deposit evaluation.

Second, this study compares the performance of different oils in the JASO clutch friction test (SAE#2) and in a fired-engine Scooter Fuel Economy Test. The results indicate that JASO MB performance, as determined by the SAE#2 clutch friction test, is not necessarily a predictor of real fuel economy benefit.

CITATION: Marcella, M. and Michlberger, A., "Unique Needs of Motorcycle and Scooter Lubricants and Proposed Solutions for More Effective Performance Evaluation," *SAE Int. J. Engines* 9(1):2016.

INTRODUCTION

By year 2020, the global motorcycle and scooter population is estimated grow to over 1.1 billion units, more than double the number in 2008 [1]. With a large portion of the motorcycle and scooter population being utilized as primary modes of transportation, and given the global push for resource conservation, the importance of durability and fuel economy is increasing. One approach for enhancing durability and improving fuel economy is through the use of engine oils formulated to optimize the performance of the intended application.

Motorcycle oils, as compared to scooter and passenger car oils, are clearly subjected to the most diverse conditions. Whereas passenger cars and scooters traditionally have separate engines and transmissions, motorcycles are typically one unit, with the crankcase, clutch, and gearbox all lubricated by the same fluid. Consequently, motorcycle oils must be formulated to simultaneously protect the gears, enable efficient wet-clutch operation, and still effectively lubricate and protect the crankcase.

In addition to these differences, the crankcase environment of both motorcycles and scooters itself, is more severe than most passenger cars. Operating temperatures, especially for air-cooled engines, are generally higher than passenger cars, which is significant in that air-cooled models make up the majority of the global market [1]. Further, both motorcycles and scooters typically also have higher compression ratios, run at higher engine speeds, and have much higher power densities than passenger cars, all placing higher demand on the lubricant.

The key difference between scooters and motorcycles, as pertaining to this study, is that scooters do not traditionally employ a wet-clutch or gearbox lubricated by the crankcase oil. As such, scooter oils can be formulated to provide fuel economy benefits on the level of passenger car oils through lower viscosity grades and proper additive chemistry.

Currently, the crankcase-specific performance of motorcycle and scooter oils licensed under the JASO T 903:2011 standard is supported by the oil's ability to meet the requirements of one of the numerous passenger car performance categories as defined by API, ILSAC, or ACEA [2]. The first portion of this two-part study compares the API Sequence IIIF test with an air-cooled motorcycle engine test on the ability to differentiate motorcycle oils for piston deposit control. The second part of this study looks to determine if a correlation exists between JASO MB performance, as determined by the JASO clutch friction test, and actual fuel economy benefit.

PISTON DEPOSIT CONTROL COMPARISON

Test Methods

The methods used for this portion of the study were the API Sequence IIIF (ASTM D6984) engine test and an air-cooled motorcycle piston deposit test developed by The Lubrizol Corporation. The motorcycle test was developed with the intent to have a method available for evaluating oil performance under the severe operating conditions of an air-cooled motorcycle. The basic operating conditions of both tests are provided in Table 1. Complete operating conditions for the Sequence IIIF are found in ASTM D6984-14a.

Table 1. Engine Test Operating Conditions [3]

Test	MCO Evaluation	API Sequence IIIF
Engine	Yamaha TT-R125	GM Series II V6
Displacement (liters)	0.125	3.8
Engine Speed (RPM)	7500	3600
Power (hp/kW)	8.85/6.6	125/93.2
Power Density (hp/liter)	70.8	32.9
Duration (hours)	24	80
Oil Temperature (°C)	115	150

The motorcycle test utilizes a Yamaha TT-R125 air-cooled single-cylinder engine. Oil sump temperature and spark plug temperature are held constant at $115\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ and $220\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, respectively. The engine is run for 24 hours at 7,500 RPM under a constant load of 6 kW applied by a dynamometer. The oil sump temperature is held fairly low to minimize the amount of fresh oil additions needed, which during test development was found to decrease test severity and thus the ability to effectively differentiate between oils.

At the end of the both tests, the engines are disassembled and engine parts are rated according to ASTM Manual 20, with the Sequence IIIF using a weighted scale for average deposits and the Yamaha an arithmetic average. Deposits and varnish are both rated using a merit scale, with 10 being the best possible rating and 0 being the worst. The test oils are drained and various analyses such as kinematic viscosity (KV), total base number (TBN), and drain elements are performed. As these are API SJ oils, for the Sequence IIIF, the KV data are taken at 60 hours, while the engine parts are rated after the full 80-hour test duration.

Results

Both the motorcycle oil (MCO) and the passenger car motor oil (PCMO) used here meet the requirements of API SJ and JASO MA2. Both were formulated to similar viscometrics in 15W-40 viscosity grades using Group II base stocks and Olefin Copolymer (OCP) viscosity modifiers. These formulations are considered equivalent, with the exception being the intended end-use for which the additive chemistries were developed.

The critical Sequence IIIF results of both oils are compared in Table 2 against the API SJ limits. The results clearly display the superior performance of the motorcycle oil in all critical parameters. The motorcycle oil shows much better resistance to oxidative thickening, and improved detergency over the PCMO, as evidenced by the small increase in kinematic viscosity, and extremely high merits for both weighted piston deposits and average piston varnish. Furthermore, the motorcycle oil also shows improved wear protection, a performance aspect critical for gear protection.

Table 2. Sequence IIIF Results

Oil	MCO	PCMO	
API Performance	API SJ	API SJ	
JASO Performance	MA2	MA2	
Viscosity Grade	15W-40	15W-40	SJ Limit[4]
KV Increase @40°C @60 hrs (%)	36.3	221.2	325 max.
Average Cam + Lifter Wear (µm)	3.2	8.2	20 max.
Weighted Piston Deposits (merits)	6.2	4.1	3.2 min.
Average Piston Varnish (merits)	9.4	9.1	8.5 min.
Hot Stuck Rings	0	0	None

The same 15W-40 oils were then run in the fired motorcycle test, the results of which are presented in Table 3. Because of the short duration of this test, viscosity increases were essentially equivalent and are not presented here.

Table 3. Motorcycle Test Results

Oil	MCO	PCMO
API Performance	API SJ	API SJ
JASO Performance	MA2	MA2
Viscosity Grade	15W-40	15W-40
Ring Groove Average Deposits	6.5	2.7
Piston Land Average Deposits	9.1	7.3
Piston Skirt Average Varnish	9.0	8.8
Undercrown Deposits	6.5	1.0
Total Average Deposits	7.4	3.7

As in the Sequence IIIF, the motorcycle oil again displays superior deposit control performance. While the motorcycle oil is better on all measured parameters, of particular interest in this air-cooled environment is the improvement to the piston undercrown rating, the cleanliness of which is critical for heat transfer and thus engine cooling. Further, the PCMO's low rating for ring groove deposits is