

Improving Fuel Efficiency of Motorcycle Oils

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ABSTRACT

As the motorcycle market grows, the fuel efficiency of motorcycle oils is becoming an important issue due to concerns over the conservation of natural resources and the protection of the environment. Fuel efficient engine oils have been developed for passenger cars by moving to lower viscosity grades and formulating the additive package to reduce friction. Motorcycle oils, however, which operate in much higher temperature regimes, must also lubricate the transmission and the clutch, and provide gear protection. This makes their requirements fundamentally very different from passenger car oils. Developing fuel efficient motorcycle oils, therefore, can be a difficult challenge. Formulating to reduce friction may cause clutch slippage and reducing the viscosity grade in motorcycles must be done carefully due to the need for gear protection. Additionally, in high temperature motorcycle engines, low viscosity oils are more prone to oil consumption, which will negatively impact fuel economy. They also may cause more deposit formation, which can reduce overall performance.

The lowest viscosity grade oil currently recommended by Honda for motorcycle applications is a 10W-30. This study describes the development of a new 5W-30 motorcycle oil to deliver enhanced fuel efficiency in motorcycle engines. The key target of this development was to deliver enhanced fuel efficiency with a 5W-30 while not compromising any of the performance of the current high quality 10W-30 oil. Testing was conducted to validate oil consumption, clutch performance, oxidation resistance, wear protection, gear protection, and engine cleanliness in modern Honda motorcycle engines. In all aspects, the newly developed 5W-30 oil performed equivalent to or better than the high quality 10W-30 reference oil. As the final proof of performance, the new 5W-30 oil was compared with the 10W-30 reference oil in a motored motorcycle engine friction torque test and clearly demonstrated the desired enhanced fuel efficiency.

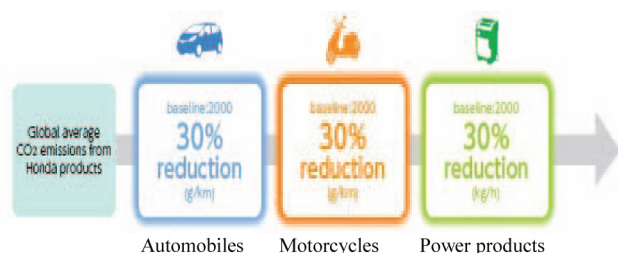
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BACKGROUND

Honda has been involved in environmental issues for many years. Since the 1980's many environmental issues have been highlighted that need to be dealt with on a global basis. Fundamentally, they strive to deal with these issues even before they are recognized as environmental issues. As such, they have published a corporate objective to achieve a 30% CO₂ emissions reduction as compared to 2000 emissions levels in all engines they produce by 2020.¹

The motorcycle market has been continuously growing, especially in Asia where 80% of the world's motorcycles are sold. This further highlights the value of reducing CO₂ emissions of motorcycles.

One way to reduce CO₂ emissions is to improve fuel efficiency. This strategy has been employed in the automobile segment with design of lower friction engines and more fuel efficient engine oils. Engine oil fuel efficiency can be improved by reducing viscosity and formulating with low friction chemistry.



Motorcycle Regions covered: Japan, North America, Europe, Thailand, India, China, Indonesia, Vietnam, Brazil, Philippines, Malaysia, Pakistan (more than 90% of global sales)

Figure 1. 2020 Product CO₂ Emissions Reduction Targets

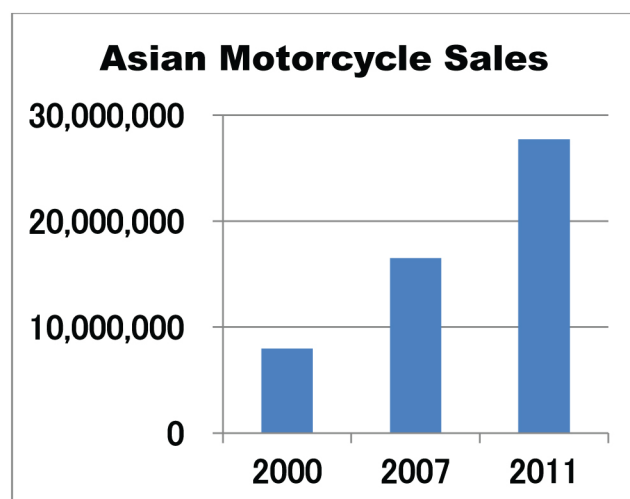


Figure 2. Growth in Asian Motorcycle Market²

While this strategy has been effective in the automotive segment, it has limitations in the motorcycle segment. Motorcycle oils operate in a much higher temperature regime and must also lubricate the transmission and the clutch, and provide gear protection. This makes their requirements fundamentally very different from passenger car oils. Developing fuel efficient motorcycle oils, therefore, can be a difficult challenge.

OIL DEVELOPMENT

The objective of this oil development was to create the most fuel efficient API SL / JASO MA2 quality low viscosity motorcycle oil, that had all the performance qualities of a current SAE 10W-30 oil. Two additional criteria were added as new development targets for this oil. The oil was to be formulated with a target 43 cSt kinematic viscosity at 40°C to maximize fuel economy and the oil was also to be formulated to a target of 12% NOACK to control oil volatility. Lower viscosity improves fuel efficiency while lower volatility enables the oil to maintain its fuel efficiency throughout use in the engine.

As a result, an SAE 5W-30 oil was developed to meet these criteria. The formulation shape and oil properties of this oil are shown in [table 1](#).

Table 1. Formulation and Properties

BASE OIL	Group III
VISCOSITY MODIFIER	PMA-type
ADDITIVE PACKAGE	MCO-type
D2270	
VISCOSITY 40°C cSt	43.33
VISCOSITY 100°C cSt	9.36
VISCOSITY INDEX	207
D4683	
VISCOSITY 150°C cP	3.09
D5293 (-30)	
CCS -30°C cP	3820
D5293 (-35)	
CCS -35°C cP	7330
D5800	
VOLATILITY, NOACK	
% EVAPORATIVE LOSS	11.6
D6278	
30 PASS SHEAR STAB	
% VISCOSITY LOSS	2.71
NEW OIL VIS 100°C cSt	9.38
USED OIL VIS 100°C cSt	9.13

The oil was formulated with all Group III base oil to optimize the viscometrics within the 5W-30 grade while minimizing the volatility to ensure fuel economy durability. In addition, a unique polymethacrylate (PMA) was used as a viscosity modifier. It was chosen because PMA's are known to improve fuel efficiency. In addition, this particular PMA was chosen due to its shear stability. Utilizing a very shear stable PMA enables formulating to lower viscosity without the oil shearing out of grade. Finally, an additive approach was developed to provide the enhanced durability needed for a 5W-30 motorcycle oil in modern engines. In addition to components present to meet the API SL performance level, several motorcycle specific components were utilized such as:

- chemistry to enhance clutch performance and minimize clutch slippage.
- thermally stable detergent system designed for high temperature motorcycle applications
- gear protection components for gear pitting protection in this low viscosity 5W-30
- additional antioxidant chemistry for high temperature conditions as well as to provide fuel economy durability by preventing oxidative thickening
- low volatility zinc dialkyl dithiophosphate to minimize catalyst poisoning, hence further reducing emissions.

This oil was then tested in a series of bench tests designed to evaluate some basic properties such as corrosion protection and deposit formation. In all cases, the oil performance was outstanding.

Table 2. Bench Testing Results

D6557	
BALL RUST TEST	
AVERAGE RUST RATING	139
D130	
COPPER STRIP CORROSION	
TEMPERATURE °C	100
COPPER RATING	1A
TEST LENGTH hr	3
D6335	
TEOST 33C	
TOTAL DEPOSITS mg	42
D7097 B	
MHT TEOST	
TOTAL DEPOSITS mg	35

Then the clutch friction performance was evaluated using the JASO T903:2011 test procedure. The oil easily met the criteria for JASO MA2, the highest JASO performance level for a motorcycle oil.

Table 3. Clutch Testing Results

	Friction Performance Index & Classification					
	Dynamic Friction (DFI)		Static Friction (SFI)		Engagement Time (STI)	
Index	2.00	MA2	1.96	MA2	2.00	MA2
Class						
MA2 class	≥ 1.85 and < 2.50		≥ 1.70 and < 2.50		≥ 1.85 and < 2.50	
MA1 class	≥ 1.30 and < 1.85		≥ 1.25 and < 1.70		≥ 1.45 and < 1.85	
MB class	≥ 0.50 and < 1.30		≥ 0.50 and < 1.25		≥ 0.50 and < 1.45	

Since motorcycle engine oil is also lubricating the transmission gear box, the low viscosity oil was also checked for gear protection performance. The load carrying capacity performance was evaluated using the ASTM D5182 (CEC L-07-95) test procedure in a FZG test rig. The results in this test show the 5W-30 candidate had equivalent performance compared to the high quality 10W-30 reference oil.

Table 4. FZG Gear Test Results

Test Conditions	Failure (Scuffing) Load Stage	
	Reference	Candidate
FZG Type A Gears Speed: 1450 rpm Oil temperature: 90°C	Load Stage 11	Load Stage 11

Next, fatigue life performance was evaluated using a needle roller bearing pitting test on a uni-steel bearing tester.

Thrust needle roller bearings are used to simulate gear fatigue conditions due to their sliding operation

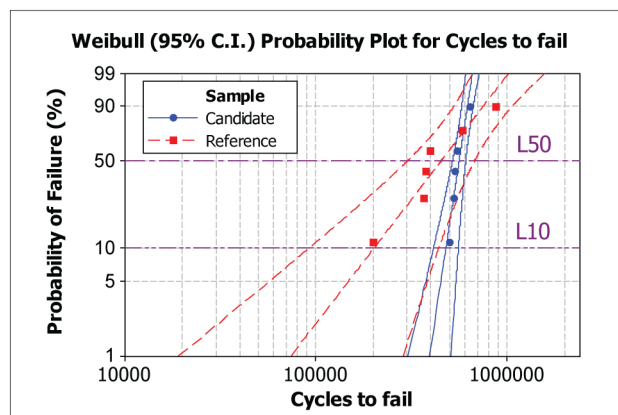


Figure 3. Weibull Probability Plot

In this test procedure, NSK FNTA2542 thrust needle roller bearings with reduced rolling elements are set up in an oil bath at 120°C to operate under maximum contact stress of 2.2 GPa and the peripheral speed of 2.6 m/s at the mid-point of needle rollers. The occurrence of pitting on needle rollers is detected using an accelerometer and the number of cycles to fail is recorded. Pitting life is evaluated based on L10 and L50 life indices derived by Weibull probability analysis on multiple (N = 6) test run data.

Figure 3 shows the Weibull probability plot comparing failure probabilities of the candidate versus reference oils. Accordingly, the candidate oil shows significantly better fatigue life in L10 and equivalent fatigue life in L50. This further supports equivalent gear pitting protection of the candidate 5W-30 compared to the 10W-30 reference oil.

ENGINE TESTS

In addition to bench tests, four engine tests were used to validate oil performance. In each engine test, a 'reference' test was conducted using the current high quality 10W-30 oil to determine acceptable performance. Table 5 summarizes each engine test.

Table 5. Test Engine Summary

	Engine 1	Engine 2	Engine 3
Cooling Type	Air Cooled	Air Cooled	Liquid Cooled
Number of Cylinder(s)	1	1	4
Displacement	110 cc	230 cc	600 cc
Valve Train System	OHC 2-Valve	OHC 2-Valve	DOHC 16-Valve
Transmission (speed)	4	5	6
Test Purpose	Valvetrain Wear	Transmission Gear Durability	Overall Performance Evaluation
	Viscosity Increase	Overall Performance Evaluation	

Valvetrain Wear Testing

This test uses 110 cc air cooled engine (Engine 1) driven by an electric motor. Engine speed is low to induce boundary