

# Highly Efficient Lubricant for Sport Motorcycle Application - Fuel Economy and Durability Testing

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## ABSTRACT

As a result of extremely competitive market environment and severe emission legislation, motorcycle manufacturers are giving increased focus to the lubricant as a potential tool to improve engine performance reducing at same time tailpipe emissions and fuel consumption. However, due to very specific hardware constraints, application of highly efficient low viscosity oils to modern motorcycle requires careful formulation approach and thorough testing procedure. Previous work carried out by Castrol and described in SAE paper # [2011-32-0513](#) indicated that optimized, low viscosity motorcycle engine oils, formulated with dedicated technology to combine optimum clutch compatibility with engine and gearbox protection, can bring significant increase in engine power and acceleration in comparison with commercially available lubricants. This paper describes the progress of the development work, aiming at further understanding potential benefits and constraints arising from the application of low viscosity, highly efficient engine oils to current motorcycle engine technology. The work included the evaluation of the fuel economy potential for experimental low viscosity formulations using a sport tourer motorcycle fitted on chassis dynamometer, followed by extended high speed engine durability evaluation of one of the formulations on two different super sport motorcycle engines, representative of latest generation hardware technology. Results of Fuel Economy tests showed that carefully formulated low viscosity lubricants can provide reduction in fuel consumption when compared with conventional, commercially available products. Both the durability test programs were successfully completed with key engine and driveline components in good conditions at end of test, confirming potential applicability of low viscosity engine oils to modern high performance sport bikes.

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## INTRODUCTION

Unlike passenger car where lubrication of engine and gearbox is separated and clutch is dry type, a typical sport motorcycle powertrain uses the same fluid to lubricate engine and gearbox and cool the clutch. The lubricant must therefore fulfill a number of different and often conflicting tasks. A good motorcycle lubricant must be able to protect key engine components from wear and deposits and to control evaporation through piston ringpack under the extreme speed, load and temperatures typical of sport operations. At the same time, oil must protect small and heavily loaded gears from wear, pitting and scuffing, as well as ensure the correct level of friction between clutch plates in order to allow their smooth engagement, prevent slip under high load and protect friction material from premature wear. Considering these fundamental performance criteria, it becomes clear that a motorcycle lubricant should be formulated to provide a

thicker, more thermally and shear-stable oil film than a passenger car oil, and must have higher friction coefficient; for these reasons the application of low viscosity, low friction formulation technology for energy conserving purposes to motorcycle has been up to now a very challenging objective and, as a matter of fact, the majority of motorcycle models in the market is still serviced with conventional lubricants of relatively high viscosity (typically SAE10W-40 or above). However, due to continuous demand for increased engine responsiveness coupled with reduction of fuel consumption and tailpipe emissions, the application of low viscosity engine oils to motorcycles becomes more and more a desired step. Development of motorcycle-specific energy conserving formulation technology, followed by extensive testing using representative bench motorcycle test is therefore required in order to ensure balance between efficiency and durability.

**Table 1. n- Characteristics of Candidate and Reference Oils**

| Oil code                          | 001B                   | 002A      | 032A       | 041B                 | 003A             |
|-----------------------------------|------------------------|-----------|------------|----------------------|------------------|
| Type                              | Candidate              | Candidate | Candidate  | Reference for durab. | Reference for FE |
| Viscosity Grade                   | 0W-20                  | 0W-30     | 5W-40      | 10W-40               | 15W-40           |
| API Classification                | SL                     | SL        | SL         | SL                   | SL               |
| JASO T903 : 06 classification     | MA2 type performance * | MA2       | MA2        | MA2                  | MA2              |
| Additive type                     | A                      | A         | A          | A                    | A                |
| Base oil type                     | Group IV               | Group IV  | Group III. | Group I/III          | Group I          |
| Kinematic Viscosity @ 100 °C, cSt | 8.21                   | 9.98      | 13.0       | 12.8                 | 14.5             |
| Kinematic Viscosity @ 40°C, cSt   | 41.98                  | 54.96     | 77         | 83                   | 103.6            |
| Viscosity Index                   | 175                    | 172       | 170        | 150                  | 136              |
| HTHS Viscosity. cP                | 2.6                    | 2.9       | 3.5        | 3.5                  | 3.8              |
| Noack evaporation, % wt           | 6                      | 6         | 9          | 13                   | 13               |
| Phosphorus, % wt                  | 0.096                  | 0.096     | 0.096      | 0.096                | 0.096            |

**Table 2. Summary of rolling road and bench tests**

| Performance Area                | Test type    | Rig type / Engine / Bike type      | Test Method      | Measured parameter                                                        |
|---------------------------------|--------------|------------------------------------|------------------|---------------------------------------------------------------------------|
| Fuel Consumption                | Rolling Road | Sport Tourer 1300 cc, water cooled | Castrol in-house | Fuel Consumption (by Carbon Mass Balance)                                 |
| Engine and driveline durability | Rolling Road | 1000cc superbike, water cooled     | Castrol in-house | Used oil analysis, engine/ driveline visual rating, piston deposit rating |
|                                 | Bench        | 600cc supersport, water cooled     | Castrol in-house |                                                                           |

## EXPERIMENTAL FORMULATIONS

Two of the experimental lubricants described in SAE paper # 2011-32-0513 were used for this work. These are a SAE 0W-20 and a SAE 0W-30 formulation respectively, using fully synthetic base oils (Group IV), shear stable viscosity modifier and a motorcycle specific additive package. The additive system comprises metallic detergents, ashless dispersant, zinc - phosphorus anti-wear and a combination of ashless and metallic antioxidant. The additive system was formulated with reduced phosphorus level, with the objective of ensuring good catalyst compatibility.

A third formulation (SAE 5W40) blended with Group III base oils and same additive system of 001B and 002A was added to the test matrix in order to allow a more complete mapping of viscometric effect on fuel consumption. The experimental formulations were tested against reference oils meeting OEM requirement for each engine used for testing. In order to reduce number of variables and allow a better interpretation of test results, reference oils were formulated with same additive system of candidate oils. Details on candidates and reference oils are given in [Table 1](#).

## TEST PROGRAM

The Initial test program for clutch compatibility, power / acceleration and engine / gearbox durability carried out on 001B and 002A formulations has been summarized in SAE Paper # 2011-32-0513. For the work described in this paper, in-house rolling road Fuel Economy test method and bench and rolling road durability procedures were adopted. [Table 2](#) contains a summary of the test performed. In combination with those previously performed, these tests give comprehensive overview of candidate performance across the performance spectrum of motorcycle engine oils

## FUEL ECONOMY

Fuel Economy is one of the most challenging areas for motorcycle lubricant testing. Relatively limited differences typically given by candidate oils, along with high influence of large number of test parameters on fuel consumption trend across the experiment, can heavily affect test precision reducing discrimination between candidates and reference oil. High control of test conditions along with careful design of the experiment is therefore necessary in order to capture statistically meaningful differences. For this work, an in-house test procedure using a latest generation 4 in-line sport

tourer motorcycle fitted on rolling road was developed. The drive cycle adopted is the World Harmonized Motorcycle Drive Cycle (WMTC), which is represented in [figure No 1](#). The WMTC a highly transient cycle designed in order to represent real-life motorcycle running conditions. The cycle is 1800 seconds in total and it is divided in three 600 sec phases, representing stop and go, urban and extra urban riding respectively.

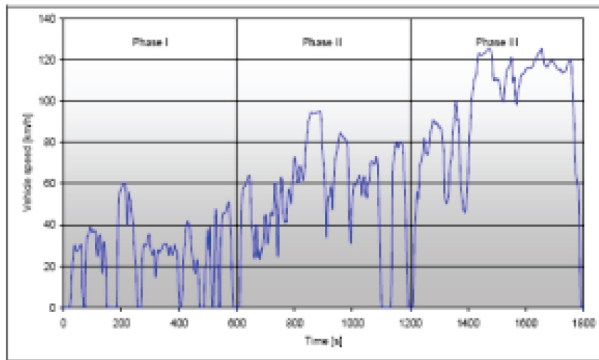


Figure 1. WMTC drive cycle

The test cycle consisted in 5 repeats of the WMTC per candidate (one cold start and 4 hot starts). Before each hot cycle, a 20 minutes constant speed engine stabilization phase was performed. For each candidate fuel consumption was measured for 1 cold start WMTC and for 3 separate hot starts (the first of the hot start cycles was a warm up and stabilization cycle and measurement was not taken). Each candidate oil run was followed by a reference run and the test matrix included three repeats for each candidate. For each single WMTC, exhaust gases were collected separately for the three stages using a bag sampling system and a CO/CO<sub>2</sub> gas analyzer. Fuel consumption was then calculated using Carbon Mass Balance Method. A snapshot of test cycle is given in [Figure 2](#). Fuel Consumption data for each candidate

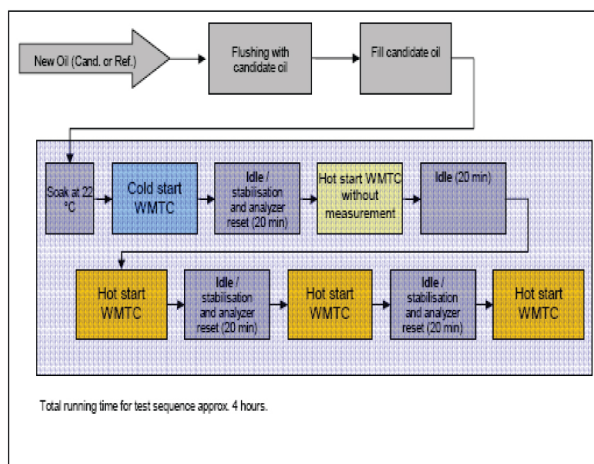


Figure 2. Test Cycle Snapshot

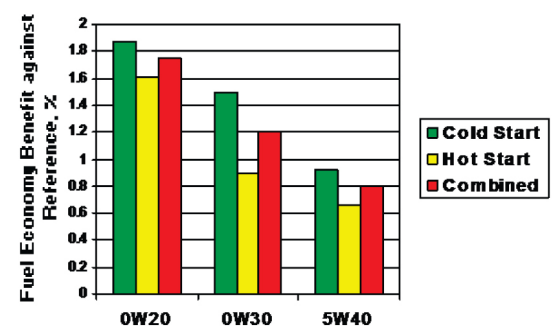
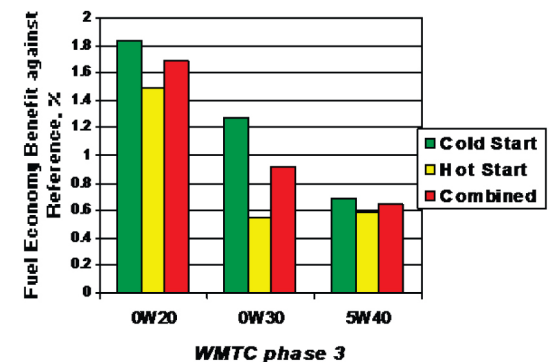
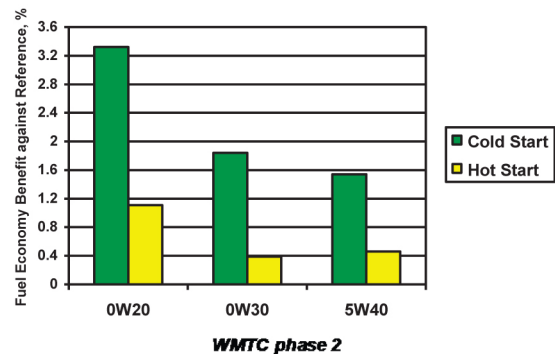
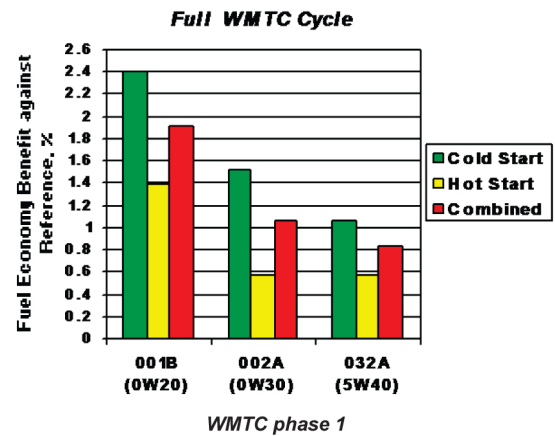


Figure 3. Fuel Economy Summary