CHAPTER 3

EXPERIMENTAL

3.1 JASO T 903 standard

The JASO T 903 standard (Appendix II) is the new industry standard requirements for four-stroke cycle motorcycle lubricants. The required physicochemical properties in this standard are shown in Table 3.1.

Table 3.1 Physicochemical properties of JASO four-stroke motorcycle engine oils.

Test Item	Performance criteria	Test procedure
Sulfated ash mass/ %	1.2 max.	JIS K 2272-85
Evaporative loss mass/ %	20 max	JPI-5s-41-93
Foaming tendency seqI Foaming/setting seqII seqIII	10/0 max 50/0 max 10/0 max.	JIS K 2518
Shear stability Kinematic viscosity after the test (100 °C)/ mm^2/s	xW-30: 9.0 min xW-40: 12.0 min xW-50: 15.0 min	JPI-5s-29-88 (30 cycles)
High temperature high shear/mPa-s	2.9 min	JPI-5s-36-91

This study investigated the effect of base oil composition and viscosity modifier type on the shear stability of fully formulated crankcase lubricants according to the new JASO T 903 criteria. Four commercially available star type hydrogenated isoprene (STAR1,STAR2) and hydrogenated isoprene styrene (STAR3) viscosity modifiers along with an olefin copolymer viscosity modifier (OCP1), which is currently used in a four-stroke motorcycle engine oil formulation, were evaluated. Physical and chemical properties of viscosity modifiers in this study can be found in Appendix III.

The viscosity modifiers were blended with the same performance additive package (Appendix IV) which claims to meet API SG specification. This specification is selected due to four-stroke motorcycle requirements needing a minimum level of API SE according to JASO T 903. The new recommendations for SAE grades for this type of engine are **X**W-30, **X**W-40 and **X**W-50 where **X** is equal to 10 or 20. All six viscosity grades were then all be included in this study with additive performance of above the minimum API SE grade set in JASO T 903. A targeted formulating procedure technique was used to obtain blended samples which satisfy JASO T 903 viscosity requirements for SAE XW-30, XW-40 and XW-50 grades where X is either 10 or 20.

Given the difficulty, inconvenience and time consumption related to data collection from field tests, a variety of laboratory methods have been devised over the years to simulate operational shear stresses. The JASO standard on four-stroke motorcycle oil proposes the Diesel injector rig (ASTM D 3945)[27] method as a standard shear test to adequately simulate the severity of this type of engine. This rig test was used as an important experimental part of this study to evaluate the shear stability of the various viscosity modifiers in terms of permanent viscosity loss. Properties of the sheared oil were then compared to those of the unsheared oil.

These industry standardised viscometric, shear stability, and other associated property tests were performed on each sample blend and all results were then compared to determine which type of viscosity modifier is the most shear stable and most suited for motorcycle application.

3.2 Apparatus

1. Kinematic Viscometer (ASTM D 445): Model 75943-1, Precision, GERMANY.

2. Cold cranking simulator (ASTM D 5293): Model CCS-4, Cannon, USA.

3. Diesel injector rig (ASTM D 3945): Kurt Orbahn DIN 51382, HEA-Hamburger Elektro Apparate Gmbh, GERMANY.

3.3 Experimental procedure

3.3.1 Preparing multigrade oil

Two types of base oil used were 150 and 500 Solvent Neutral (SN). The physical properties of these base oils can be found in Appendix V. These base oils are paraffinic type with different in viscosity ranges. The 150 SN oil has an viscosity at 100 °F of around 150 saybolt universal seconds (SUS) which equates to kinematic viscosity (KV) at 40 °C (ASTM D 445)[28] of around 30 centistoke (cSt). The 500 SN oil has an viscosity at 100 °F of around 500 SUS which equates to kinematic viscosity (KV) at 40 °C of around 100 cSt. Paraffinic base oils are made from crude oils that have relatively high alkane contents. Most of base oils produced in the world are paraffinic and they are available in the full range of viscosities. This type of base oil is also widely used in South East Asian countries due to the low cost of this base oil type. A targeted formulating procedure was used to obtain samples with targeted viscosity at 100 °C (see Model Formulation).

Model Formulation:

Detergent Inhibitor	7.8% (constant)
Viscosity Modifier	(vary with 1% increment to 10 %)
150 SN Mineral Oil	(vary depending on required viscosity)
500 SN Mineral Oil	(vary depending on required viscosity)

3.3.1.1 Preparation and viscosity determination of light and heavy base oil fractions

The method for finding appropriate proportions of 150 SN and 500 SN for a given percentage of viscosity modifier involves blending two different samples. One sample being with 150 SN base stock only and another sample with the heavier base stock (500 SN). Both of these must have the same treat rate of additive package and viscosity modifier for each sample.

ie. Heavy portion = A % of additive + B % of viscosity modifier + (100 - A - B)% of 500 SN.

Light portion = A % of additive + B % of viscosity modifier + (100 - A - B)% of 150 SN.

Example for blending 1% weight of viscosity modifier as light and heavy fractions:

For light fraction: one gram of a viscosity modifier and 7.8 grams of performance additive package were weighted into a 150 ml beaker. Then 150 SN base oil was added to make up the total content of 100 grams. The mixture was stirred with a magnetic stirrer on hotplate at 50 °C for a period of 30 minutes or until the oil solution became homogeneous.

The heavy fraction obtained with the same method above but replaced 150 SN with 500 SN. The viscosity modifier treat rates were varied from 1 -10% and also with four different viscosity modifiers. The total number of blended samples at this step was

80 samples. Each sample obtained from above was then used to determine the kinematic viscosity at 100 °C using glass viscometer (ASTM D 445).

3.3.1.2 Determination of base oil ratios for targeted kinematic viscosity at 100 °C

A computer program[29] was used to determine the amount of light (150 SN) and heavy (500 SN) contents for each particular viscosity modifier treat rate to meet one of the required SAE high temperature (100 °C) targeted viscosity grades. This program is based on method described in ASTM D 341[28] in producing the volume fractions of two given oils when blending to meet a specified kinematic viscosity at a given temperature. The required viscosity blends were calculated using the following relationships:

A volume fraction high viscosity oil at 40 °C=

$$[\frac{(E-A)(C-D)}{/(E-F)(A-C)} + 1]^{-1}$$

A volume fraction high viscosity oil at 100 °C =

$$[\frac{(F-B)(C-D)}{/(E-F)(B-D)} + 1]^{-1}$$

where:

$A = \log\log Z_{B(40)}$, $B = \log\log Z_{B(100)}$, $C = \log\log Z_{L(40)}$

$D = \log\log Z_{L(100)}$, $E = \log\log Z_{H(40)}$, $F = \log\log Z_{H(100)}$

$Z = (cSt+0.70)$

Subscripts:

B = Blend, L = Low-viscosity oil, H = High viscosity oil

(40) = 40 °C, (100) = 100 °C

For each SAE viscosity grade at 100 °C, the targeted viscosity ranges were divided into four viscosity values. The first expected viscosity value was the midpoint between the minimum viscosity value and the midpoint viscosity for each SAE 30, 40 and 50 grades, the second value was the midpoint between minimum and maximum viscosities of each grade, the third value was the mid viscosity between the midpoint viscosity and the maximum viscosity and the last value was the maximum viscosity of each grade. The targeted viscosities of each viscosity grade are listed in Table 3.2.

Table 3.2 : Targeted viscosities of formulated oil at low and high temperatures

SAE Viscosity	Viscosity[28],cSt	Viscosity Target, cSt	CCS Viscosity [18],
10W/30	9.3 - <12.5	9.3, 10.9,11.7, 12.4	3500 max@ -20°C
10W/40	12.5 - <16.3	12.5, 14.4, 15.4, 16.2	3500 max@ -20°C
10W/50	16.3 - <21.9	16.3, 19.1, 20.5, 21.8	3500 max@ -20°C
20W/30	9.3 - <12.5	9.3, 10.9,11.7, 12.4	4500 max@ -10°C
20W/40	12.5 - <16.3	12.5, 14.4, 15.4, 16.2	4500 max@ -10°C
20W/50	16.3 - <21.9	16.3, 19.1, 20.5, 21.8	4500 max@ -10°C

Calculated light and heavy base oil ratios are listed in Appendix VI.

3.3.1.3 Determination of viscosity at low temperature

Samples at each viscosity grade were blended with total weight of 100 grams according to previous base oil ratio calculations. The viscosity at low temperature tested by cold cranking simulator equipment (CCS, ASTM D 5293)[18] for each sample was tested at two temperatures; -10 °C and -20 °C (Appendix VII). The obtained cold cranking simulator viscosities were then used to compare with given values as specified in SAE J 300. All samples may meet the high temperature requirement (i.e. KV at 100°C, ASTM D445)[28] but may not meet the low temperature requirement. Only sample blend that met the requirements of both low and high temperatures, further physical property tests including kinematic viscosity at 40 °C(ASTM D 445)[28], kinematic viscosity at 100 °C (ASTM D 445)[28] and viscosity index (ASTM D 2270)[30] were then conducted.

3.3.2 Determination of viscosity modifier shear stability

The blend formulations selected from 3.3.1.3 were then used for shear stability Diesel injector rig method in standard 30 cycles shear test (ASTM D 3945)[27]. The percentage shear loss under standard condition was calculated by comparing kinematic viscosities (at 100 °C ASTM D445)[28] between sheared and unsheared samples. The blend samples which passed the JASO specification on shear stability test were then subjected to further shear stability test with 60, 100 and 250 cycles. Relative percentage shear loss was compared for each type of viscosity modifier polymer. At least one litre (approximately ten times by weight of 100 grams blend formulation) of each fully formulated multigrade oil sample was required to run this shear stability test. Details of apparatus preparation and test methods of Diesel injector rig can be found in Appendix VIII.