Designation: D 6022 – 01

# Standard Practice for Calculation of Permanent Shear Stability Index[1]



## 1. Scope

1.1 This practice specifies the procedure for the calculation of Permanent Shear Stability Index (PSSI) of an additive using viscosities before and after a shearing procedure.

1.2 PSSI is calculated for a single blend component and can then be used to estimate the effects of that component on finished lubricant blends.

1.3 This practice is applicable to many products and may use data from many different test methods. The calculation is presented in its most general form in order not to restrict its use.

## 2. Referenced Documents

2.1 *ASTM Standards:*

D 2603 Test Method for Sonic Shear Stability of Polymer-Containing Oils[2]

D 3945 Test Methods for Shear Stability of Polymer-Containing Fluids Using a Diesel Injector Nozzle[3]

D 4485 Specification for Performance of Engine Oils[3]

D 5119 Test Method for Evaluation of Automotive Engine Oils in the CRC L-38 Spark-Ignition Engine[3]

D 5275 Test Method for Fuel Injector Shear Stability Test (FISST) for Polymer Containing Fluids[3]

D 5621 Test Method for Sonic Shear Stability of Hydraulic Fluid[4]

D 6278 Test Method for Shear Stability of Polymer Containing Fluids Using a European Diesel Injector Apparatus[4]

2.2 *CEC Standards:*[5]

CEC L14A 93 Evaluation of the Mechanical Shear Stability of Lubricating Oils Containing Polymers

CEC L37 T 85 Shear Stability of Polymer-Containing Oils (FZG)

CEC L45 T 93 Viscosity Shear Stability of Transmission Lubricants (KRL)

## 3. Terminology

3.1 *Definitions:*

3.1.1 *degree of thickening (DT)*, *n*—the ratio of an oil's viscosity with an additive to that oil's viscosity without the additive. A measure of the amount by which an additive increases the base fluid viscosity.

3.1.2 *permanent shear stability index (PSSI)*, *n*—a measure of the irreversible decrease, resulting from shear, in an oil's viscosity contributed by an additive.

3.1.2.1 *Discussion*—PSSI is a property calculated for a single component. Viscosity Loss (*q.v.*) is a property measured for a finished oil.

3.1.3 *shear*, *adj*—a relative movement of molecules or molecular aggregates that occurs in flowing liquids. A shear flow is one in which the spatial velocity gradient is perpendicular to the direction of flow.

3.1.3.1 *Discussion*—Not all flow geometries meet this definition.

3.1.4 *shear*, *v*—to subject a liquid to a shear flow.

3.1.4.1 *Discussion*—Shearing an oil can sometimes cause scission of certain molecular species, resulting in a decrease in viscosity. Not all oils exhibit this response. Common ways of shearing oils to elicit this effect include injection through a small orifice and flow through gears or bearings. Irradiation with sonic energy can also decrease the viscosity of some oils.

3.1.5 *Viscosity Loss (VL)*, *n*—a measure of the decrease in an oil's viscosity.

3.1.5.1 *Discussion*—Viscosity Loss is a property measured for a finished oil. Permanent Shear Stability Index (*q.v.*) is a property calculated for a single component. Some test methods report VL as a relative change, which is dimensionless (for example, Test Methods D 2603, D 3945, D 5275, D 5621, and D 6278). Some test methods and specifications report VL as an absolute change, which has the same dimensions as the viscosity measurements (for example, Specification D 4485 and Test Method D 5119).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *base fluid*, *n*—an oil without the additive whose PSSI is to be determined. The base fluid shall have a viscosity loss of zero, within the precision of the shearing test used.

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.07 on Flow Properties.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 05.02.

[4] *Annual Book of ASTM Standards*, Vol 05.03.

[5] Available from Organization for Economic Cooperation and Development, Madou Plaza, Place Madou 1, B-1030 Brussels, Belgium.

3.2.1.1 *Discussion*—A base fluid could be a mineral oil, a synthetic oil, a formulation containing additives, or other system meeting the requirement of zero viscosity loss.

3.2.2 *sheared oil*, *n*—the test oil, after shearing.

3.2.3 *test oil*, *n*—base fluid with the additive whose PSSI is to be determined.

3.2.4 *unsheared oil*, *n*—the test oil, prior to shearing.

## 4. Summary of Practice

4.1 An index is calculated representing the change, due to shearing, in an additive's contribution to a lubricant's viscosity. A low index represents high resistance to permanent change.

4.2 Oils can be sheared by many means, including bench tests designed for that purpose, engine tests, and field service. A PSSI can be calculated for each. These indices can be used to compare the shearing severity of each test.

NOTE 1—Some methods, especially engine tests and field service, may include conditions where other effects (for example, evaporative loss, oxidation, fuel dilution, soot accumulation, and so forth.) contribute to viscosity changes. The PSSI calculated from these types of service may not be representative of pure shearing.

4.2.1 ASTM tests commonly used to shear oils include Test Methods D 2603, D 3945, D 5275, and D 5621, among others.

4.2.2 Other standards organizations publish test methods which may be suitable for shearing oils.[6]

4.2.3 An engine test, Test Method D 5119, is also commonly used to shear oils and establish a PSSI for additives.

## 5. Significance and Use

5.1 Permanent Shear Stability Index (PSSI) is a measure of the loss of viscosity, due to shearing, contributed by a specified additive.

NOTE 2—For example, a PSSI of 50 means the additive will lose 50 % of the viscosity it contributes to the finished oil.

5.2 The selection of appropriate base fluids and additive concentrations to be used in test oils is left to individual operators or companies. These choices will depend on the intended application for the additive.

NOTE 3—PSSI may depend more strongly on base fluid, additive concentration, additive chemistry, and the presence of other additives for base fluids of unusual composition (for example, esters) or if additives outside the common range of chemistries and concentrations are used. Caution should be exercised when interpreting results from different sources.

## 6. Procedure

6.1 Calculate the degree of thickening:

$$DT = V_0 / V_b \tag{1}$$

where:
$V_0$ = viscosity of the unsheared oil, and
$V_b$ = viscosity of the base fluid.

6.1.1 Viscosities shall be measured using the same test method at the same conditions of temperature and shear rate or shear stress and reported in the same units.

[6] CEC L14A 93, CEC L37T 85, and CEC L45T 93, for example.

6.2 If the degree of thickening is less than 1.2, PSSI cannot be determined from these data.

NOTE 4—Once PSSI has been determined for an additive, calculations using that PSSI can be made for oil blends where the degree of thickening is less than 1.2.

6.3 If the degree of thickening is greater than or equal to 1.2, calculate PSSI using the equation:

$$\mathrm{PSSI} = 100 \times (V_0 - V_s)/(V_0 - V_b) \tag{2}$$

where:
PSSI = Permanent Shear Stability Index,
$V_0$ = viscosity of the unsheared oil,
$V_s$ = viscosity of the sheared oil, and
$V_b$ = viscosity of the base fluid.

6.3.1 Viscosities shall be measured using the same test method at the same conditions of temperature and shear rate or shear stress and reported in the same units.

NOTE 5—If $V_b$ is close in value to $V_0$, that is if the degree of thickening is small, the denominator in Eq 2 approaches zero, and the precision of PSSI becomes unacceptable. A minimum degree of thickening of 1.2 was chosen to avoid meaningless calculations of PSSI.

6.3.2 For example, an additive is added to a base fluid of kinematic viscosity 10 $mm^2/s$ at 100°C, resulting in an unsheared oil kinematic viscosity of 15 $mm^2/s$ at 100°C. After a shearing test, the sheared oil has a viscosity of 13 $mm^2/s$ at 100°C. The PSSI of the additive is calculated as:

$$DT = 15/10 = 1.5 > 1.2 \tag{3}$$

$$\mathrm{PSSI} = 100 \times (15 - 13)/(15 - 10) = 100 \times (2/5) = 40 \tag{4}$$

6.4 Re-arranging Eq 2 gives other useful relationships. The viscosity of a formulation, after shearing, could be estimated as:

$$V_s = V_0 - (\mathrm{PSSI}/100) \times (V_0 - V_b) \tag{5}$$

or

$$V_s = V_0\ (1 - \mathrm{PSSI}/100) + V_b \times (\mathrm{PSSI}/100) \tag{6}$$

and the viscosity of the unsheared oil is:

$$V_0 = [V_s - V_b \times (\mathrm{PSSI}/100)]/[1 - (\mathrm{PSSI}/100)] \tag{7}$$

6.4.1 For example, using an additive with a PSSI of 50 and a base oil of kinematic viscosity 8 $mm^2/s$, it is desired to have a sheared oil of no less than 12 $mm^2/s$. To what kinematic viscosity should the unsheared oil be blended?

$$V_0 = [V_s - V_b \times (\mathrm{PSSI}/100)]/[1 - (\mathrm{PSSI}/100)] \tag{8}$$
$$= [12(8)(0.5)]/[1 - 0.5] = 16$$

NOTE 6—The PSSI of the additive must be determined using the same shearing test method as the specification to be met.

## 7. Report

7.1 If the degree of thickening is less than 1.2, report PSSI cannot be determined by this practice.

7.2 If the degree of thickening is greater than or equal to 1.2, report the calculated PSSI to the nearest whole number, the test method used for shearing, the test method used to measure viscosity, the identity of the base fluid, and the degree of thickening.

## 8. Precision and Bias

8.1 The calculation of PSSI is exact, and no precision limits can be assigned to this calculation.

8.2 The accuracy of calculated PSSI will depend on the precision of the viscosity determinations and the precision of the shearing method.

8.3 See Appendix X1 for a discussion of the expected variation in PSSI.

8.4 *Bias*—The calculation of Permanent Shear Stability Index is exact, and no bias can be assigned to this calculation.

## 9. Keywords

9.1 permanent shear stability index; shear; shear stability index; viscosity loss

# APPENDIX

**(Nonmandatory Information)**

## X1. EXPECTED VARIATION IN SHEAR STABILITY INDEX CALCULATIONS

X1.1 Although the calculation of PSSI is exact, given the input data, that input data can vary for repeat determinations on a single sample. This variation can propagate into the calculation of PSSI.

X1.2 If two operators are given the same raw data of viscosities, they will calculate the same PSSI.

X1.3 If two operators are given samples of the same unsheared oil, sheared oil, and base fluid for the determination of PSSI, their results are expected to differ due to the finite precision of viscosity determinations. Standard formulae for the propagation of errors[7] suggest the resultant relative error in PSSI will be approximately twice the relative error of the viscosity measurements. For example, if the reproducibility of each viscosity measurement is 0.7 % of its mean, the expected error of PSSI is approximately 1.4 % of its mean.

NOTE X1.1—The relative errors of the three kinematic viscosity measurements introduce a factor of approximately $\sqrt{3}$ into the relative error of PSSI. To the nearest whole number, this will be two times the relative error of a single kinematic viscosity test result.

X1.4 If two operators are given samples of unsheared oil and base fluid to conduct a shearing test and subsequent determination of PSSI, their results are expected to vary due to the precision of the shearing test as well as the precision of the viscosity determinations. Standard formulae for the propagation of errors[7] suggest the resultant relative error in PSSI will be approximately the sum of the relative errors of a single viscosity measurement and the relative error of viscosity loss from shearing method. For example, if the reproducibility of the base fluid viscosity measurement is 0.7 % of the mean and the reproducibility of viscosity loss in the shearing method is 5.22 %, the expected error of PSSI is approximately 6 %.

[7] Ku, H. H., "Notes on the Use of Propagation of Error Formulas," *Journal of Research of the National Bureau of Standards*—C. Engineering and Instrumentation, Vol 70C, No. 4, pp. 331–341, October–December 1966.