EVALUATION OF LOW-TEMPERATURE PUMPABILITY OF ENGINE OILS (REVIEW)

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When internal combustion engines are started at low ambient air temperatures, the feed of engine oil to the rubbing parts is hindered; the oil pump has difficulty in picking up the thickened or solidified oil, and air may be sucked into the lubrication system [1-3]. If the quantity of oil reaching the bearings, valve-drive mechanism, and other parts is inadequate, these parts may show increased wear [4-6]; and, in certain cases, the engine may fail entirely [7]. In view of this situation, the study of the low-temperature pumpability of engine oils is currently a matter of great importance.

Here we are presenting a brief review of recent non-Soviet research on engine oil pumpability.

The factors influencing the low-temperature pumpability of engine oils may be classed according to whether they relate to oil quality, engine design features, or operating conditions.

Among the main design features of engines that determine oil pumpability, we should mention the following: size of openings in oil-pump intake screen, diameter and length of pump intake pipe, location of oil pump, pressure created by the pump in the lubrication system, and hydraulic resistance of the pump and lines through which oil is fed to the rubbing parts of the engine [2-4].

In tests on SAE 10W, 20W, 5W-20, and 10W-30 oils, it was established [1] that the oil pump begins to suck air whenever the oil flow rate through the pump intake pipe falls to 6-7 cm³/sec. Under these conditions, the oil viscosity corresponds to a critical value of some 2000 cP at a shear gradient of 25-50 sec⁻¹, which is the limiting viscosity for oil pumping [2].

Under normal operating conditions, we find rather high suction-pressure differentials in the intake pipe of the oil pump (up to 660 cm H₂O) [4], as well as high shear gradients in the main oil line (2,000 to 40,000 sec⁻¹ at engine speeds of 200-1500 rpm) [8].

In evaluating engine oil pumpability in an engine installed in a cold chamber, the lubrication system of the engine is first flushed thoroughly (2-3 times) with oil, cranking the engine briefly on oil that has been preheated to 75-90°C [5, 7, 9]; after each such operation, fresh oil is charged to the system.

The length of the period for subsequent cooling of the engine and holding at the given test temperature is generally set at 16-17 h, so that one test can be run each day. An extension of the engine cold-soak period to 64 h does not affect the results obtained in the evaluation of engine oil pumpability [7].

In evaluating the pumpability of the test oil, the engine is turned over (cranked) by means of a constant-speed electric motor, and the entry of oil to various points of the lubrication system is noted, along with readings of oil pressure at these points.

The use of the electric-motor engine drive is an expedient to eliminate dilution of the oil with fuel and to provide a constant engine speed in all experiments [6]. A speed in the range of 750-1650 rpm is selected obviously, n = 750 rpm is preferable, since this is closer to the minimal engine speed after a cold start [9].

The following criteria may be taken into account in rating the low-temperature pumpability of engine oils: (a) the time required to establish normal pressure in the lubrication system [4, 7]; (b) the lubrication-system pressure reading at some particular moment in the test [3]; (c) the time required for oil to reach the most distant points of the lubrication system (passages in valve rockers) [5-7]; (d) the lowest test temperature at which normal pressure is established at specific points of the lubrication system during a certain period of engine turnover [3, 7, 9, 10].

At n = 1600 rpm, normal pressure is established in the lubrication system within 20-60 sec if the oil pumpability is entirely satisfactory; at the lower speed of 1000 rpm, this time is doubled [3, 7]; and at n = 750
rpm, a 5-min period for the oil feed pressure to the valve rockers to reach the required value may be considered to be normal [9]; this is illustrated in Fig. 1.

If the oil does not enter the pump in sufficient quantity, the pressure in the lubrication system will vary over a prolonged period, without reaching the required level, and oscillations due to air suction and other factors may be observed (Fig. 2).

In evaluating the pumpability of engine oils in repeat tests, the deviation between successive values obtained for the time to establish normal pressure in the engine lubrication system should not be greater than ±10% of the arithmetic mean value [7]; the repeatability of results in the determination of minimal temperature for engine oil circulation is ±1°C [3, 9].

Also used in evaluating the pumpability of oil in engines are various laboratory methods. They are based on determinations of low-temperature viscosity of the oil [4, 7-12] or efflux time from a calibrated container [5, 11], or they may involve the use of a laboratory unit equipped with an oil pump to determine the limiting temperature at which the pump will deliver 2.5 liters of oil at a rate above the minimal allowable rate [1].

The apparatus most often used in determining motor oil viscosity at low temperatures is the CCS (Cold Cranking Simulator), as specified in the SAE classification, or the Brookfield viscometer. With the CCS, the oil viscosity is determined in accordance with the ASTM D 2602 method at −18°C and −29°C; the shear rates realized in the CCS instrument range from 60,000 to 150,000 sec−1 [8]. For the Brookfield viscometer (ASTM D 2983−71T method), the typical shear rates are lower [11, 12]; the oil temperature for tests in this viscometer is selected within the range of −18°C to −35°C.

The Sun Oil method [5] consists of a determination of the efflux time of 300 cm³ of oil from a 1-liter horizontal container, charged with 700 cm³ of test oil; the container with the test oil is first held for 16 h at −29°C.