PUMPABILITY AND VISCOSITY TESTS OF CRANKCASE OILS

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INTRODUCTION

Multi-grade lubricating oils, for example, the SAE 5W-20 and 10W-30 oils, have come into wide use since their introduction twelve to fifteen years ago. Formulated with polymeric additives which can account for 50% or more of their viscosity, these oils are are designed to give the oil consumption properties of SAE 20 and 30 oils and, at the same time, have low viscosities at 0°F. which are required for cold starting.

The viscosity behaviour of multi-grade oils, because of the polymeric additives, differs from that of straight mineral oils in two important aspects. Firstly, oils containing polymeric additives show a decreasing viscosity as shear rates are increased. This decrease in viscosity is temporary, although continued shearing of the oil usually results in a permanent viscosity loss (when the high shear conditions are removed Secondly, the conventional (extrapolation) method for predicting the viscosity of mineral oils at different temperatures does not hold for multi-grade oils.

During the winters of 1961-66 the Agricultural Engineering Department, Universityof Manitoba, conducted various tests on winter crankcase oils. Some of the tests were carried out by fourth year Mechanical Engineering students students as an undergraduate thesis requirement. This paper deals only with the pumpability and viscosity characteristics of multi-graded oils.

PROCEDURE

1. *Viscosity Measurements*

One of the methods used for viscosity measurement was the falling ball viscometer. Absolute viscosity was obtained by measuring the velociy of a ball falling through the fluid. Balls made of different materials and sizes permitted viscosity measurements through a very wide range. Reynolds Number, however, had to be less than one or Stoke's Law would not apply. Viscosity measurements on a 5W-20 and a 5W oil were made by Walker (1) with a falling ball viscometer at temperatures ranging from 70° to 0°F. The wax in the oils made it almost impossible to see the balls below the cloud point temperatures. The measurements indicated that the 5W actually became more viscous than the 5W-20 at temperatures below 25°F. Despite the low shear rate of the falling balls, no upward hook in the logarithmic viscosity-temperature curve was noticed (measurements below 0°F., however, were not made).

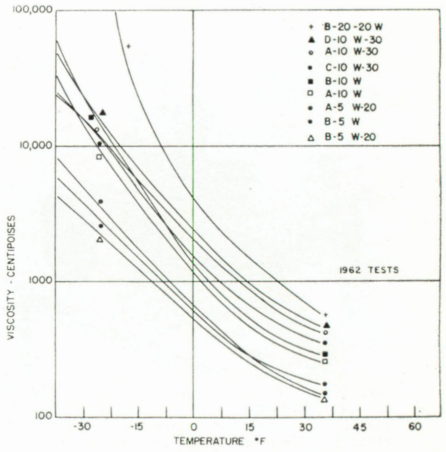

Figure 1. Viscosity Vs. Temperature of Crankase Lubricating Oils.

Other viscosity measurements were made on the same two oils with a 4-speed (2, 4, 10, 20 rpm), 7 spindle Brookfield Viscometer. The same "cross-over" of viscosity occurred at close to the same temperature (see A-5W-20 and B-5W in figure 1). Thus, if these viscosity tests are a measure of winter engine performance the 5W-20 oil tested would be equal to or better than the 5W oil. This, of course, would not be true for all 5W-20 oils (or for 10W-30 compared to 10W oils).

Recently, several companies have been marketing oils with an SAE designation of 5W-10W-20W-30 (5W-30). Viscometrically, (Brookfield) these

TABLE NO. I. VISCOSITY IN CENTIPOISES (BROOKFIELD)

Oil Number and Grade

Temperature	5W-20 1	5W-20 2	5W-20 3	5W-30 4	5W-30 5	5W 6
60	67.5	71.5	70	123	123	61
50	78.5	95.0	95.0	162	169	82
40	123.0	135.0	134.0	220	238	120
30	177.0	207.0	324.0	325	355	165
20	266.0	323.0	324.0	540	580	271
10	420.0	480.0	433.0	940	736	443
0	690.0	825.0	784.0	1750	1500*	800*
—10	1400*	1750.0				

1966 Tests

*Extrapolated

TABLE NO. II. OIL PROPERTIES

	Oil Numbers 1	2	3	4	5	6
Kin. Visc. (CS) @ 100°F.	31.02	32.01	31.24	58.60	51.55	26.7
@ 210°F.	6.41	6.24	5.92	12.59	10.92	5.11
Visc. @ 0°F. SUS (extrap.)	3250	4500	4000	3900	3900	3500
@ 100°F.	145.80	150.30	146.80	271.40	239.30	127
@ 210°F.	47.20	46.70	45.60	68.70	62.60	43
SAE No.	5W-20	5W-20	5W-20	5W-30	5W-30	5W
Viscosity Index (V.I.)	152	144	138	154	156	132
Pour Point °F.	—40	—30	—60	—30	—35	—30

1966 Tests

oils are not equal to 5W or 5W-20 oils as tested by Wilson (2) (tables I and II). As far as engine cranking is concerned, the higher shear rates involved could narrow the gap between 5W-30 and 5W-20 oils.

Correlation between low temperature viscosity measurement and engine cranking has been the object of an ASTM Committee for several years. It apears that a fairly good correlation between engine viscosity and measured viscosity is obtainable with two types of high shear rate viscometers; the Forced Ball and the Pressure-Cone. The Brookfield Viscometer, which is a low shear instrument, does not correlate very well with engine cranking speeds. If, however, an oil has a low Brookfield viscosity it should have good cranking characteristics. On the other hand, oils with higher Brookfield viscosities may perform satisfactorily in an engine where the higher shear rates tend to counteract the effect of wax formation and polymer gelation.

2. *Oil Pumpability*

Oil pumpability was tested with General Motors oil pumps driven with an electric drill at 440 rpm. The time to pump a certain quantity of oil (3 or 4 lbs.) was measured at temperatures ranging from —35°F to 50°F. A considerable number of oils were checked with this apparatus in 1962 (figure 2). In general, the multi-graded oils had low temperature pumpability characteristics similar to their straight graded counterparts. However, Wilson (2) found that the 5W-30 oils did not pump like 5W or 5W-20 oils (see table III). The 5W-30 oils had approximately a 10°F lag as compared to 5W or 5W-20 oils. That is, the 5W-30 oils @ 0° had approximately the same flow rate as the 5W and 5W-20 oils had at —10°F.

TABLE NO. III. RESULTS OF PUMPING TESTS

(Time in Seconds to Pump 3 lbs.)

Temperature	1	2	3	4	5	6
	5W-20	5W-20	5W-20	5W-30	5W-30	5W
60	10.8	11.0	11.2	12.0	11.5	9.0
50	10.9	11.0	12.0	12.0	12.0	10.0
40	11.0	11.0	12.5	14.0	14.0	10.6
30	12.8	12.8	14.5	16.5	16.2	12.0
20	15.4	17.8	19.8	21.0	21.0	14.0
10	20.8	22.0	22.0	29.0	29.0	20.0
0	27.0	29.0	30.0	43.0	42.0	31.0
—10	46.0	44.0	42.0			
—20	67.0	63.0	69.0			

1966 Tests

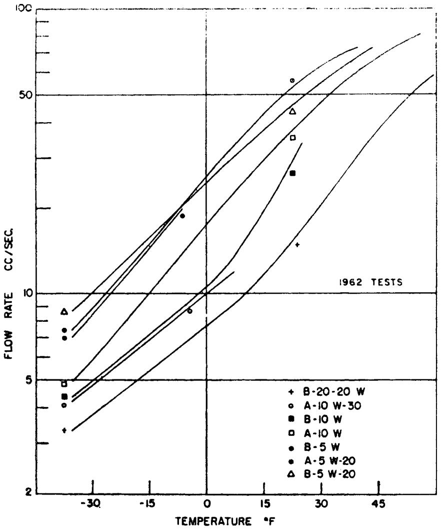

Figure 2. Flow Rate Vs. Temperature of Crankcase Lubricating Oils.

The test results from figures 1 and 2 confirmed an expected general relationship between viscosity and pumpability (figure 3). The rate at which an oil is pumped throughout the engine gives an indication of the lubrication received at low temperatures but does not necessarily predict the cranking performance of the engine.

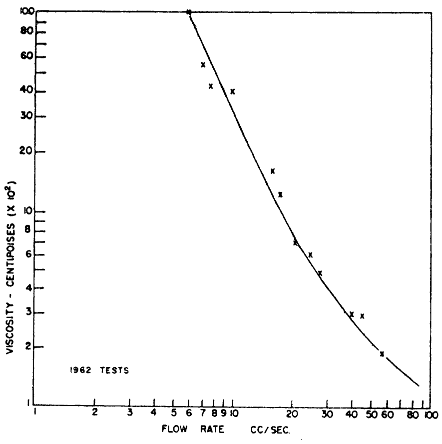

Figure 3. Viscosity Vs. Flow Rate of Crankcase Lubricating Oils.

3. *Viscosity Los and Oil Consumption*

Other important aspects of multi-graded crankcase oils are viscosity loss and oil consumption. Five oils, including two SAE 5W-30 oils, were used in a 1953 Chevrolet engine delivering 40 bhp at 2000 rpm. Oil temperature during each test was 200°F, while the coolant temperature was kept at 180°F.

Oil consumption for an eight hour test run never exceeded 0.5 lbs. which was not considered excessive. Different results may be obtained in engines that are prone to oil consumption (or are run at higher speeds).

The viscosity loss (at 210°F) is shown in table IV for one brand of SAE 5W-30 oil. Similar results were obtained with the second SAE 5W-30 oil tested. Of considerable interest is the drop in viscosity of approximately 8 to 9 Saybolt Universal Seconds (S.U.S.) after three hours of operation. A permanent viscosity loss of twelve to thirteen S.U.S. (or 30%) could be expected with these two oils. Thus, a 5W-30 oil becomes a fairly stable 5W-20 oil after several hundred miles of driving. Fuel dilution was found to be only 2% which would not markedly affect the viscosity.

TABLE NO. IV. VISCOSITY LOSS TESTS ON 5W-30 OIL

Run I

Time of Test (Hours)	Viscosity @ 210°F (S.U.S.)
0	66
4	56.6
12	54.2
16	53.2

Run II

Time of Test (Hours)	Viscosity @ 210°F (S.U.S.)
0	67.5
.5	61.5
1.0	60.2
1.5	59.1
2.0	58.4
3.0	57.1
4.0	56.4
5.0	55.5

Viscosity losses in the range of 8-20.4% at 210°F have been reported by West and Selby on 10W-30 oils

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with the right rather than the left hand of a non-ambidextrous operator. The difference between the extremes is over 1 second in favour of the absence of precision, which should only be required of an operator when it is going to make some genuine contribution to the work he performs. This principle of avoiding precision wherever possible can be extended to the design of the size and locations of levers and controls on any item of farm machinery.

Natural Arcs of Movement

Figure 2 is a view of a driver on the seat of a Massey Ferguson 175 Tractor using a steering wheel (SW) and hydraulic control (HC). The contracts in speed between the lower arc, SW-HC and the upper arc, HC-SW can be seen. This is a reflection of the known fixed location in the field of view of the SW and the unseen variable position of the HC. Note also the smooth arc of movement of the very well designed HC lever.

The comet tails point in the direction of actual movement. The black arrows show the position of "blips" which have nearly become invisible against a light background.

Movements Between Controls

Figure 3 contains three photographs of a driver on an International Harvester B414 Diesel tractor.

A—is the start up routine followed by steering and movement of the hand to the rear hydraulics.

B—is the start up routine followed directly by hand movement to the rear hydraulics.

C—is the operation of front mounted hydraulics into a definite location. Note the three positions of the control lever knob. Note also the convenient location and short arc of movement required for this control.

The arcs of movement of the hands between the starter and the hydraulics are, to the uninitiate, a surprisingly curved arc, which would naturally circumvent an obstacle placed by a designer in a straight line between the two.

The series also shows how the machine times between the start and the movement of the front hydraulics or movement of the rear hydraulics can be recorded by noting the operative's reactions. It should also be noted that the time required for manual control selection is not directly related to the distance between controls but rather to their visibility and predictable positioning.

Operators Methods and Training

The assembly of a clinch-pin onto the lower hydraulic link connecting a 3 bottom plow onto a David Brown tractor is shown in figure 4. The flashes were taken at 250 per minute. The first sequence is of a two handed method and the second of a single handed method. The second sequence is obviously the faster. The faster method was identified by motivating the operative to perform the work as quickly as possible and this showed that he was subconsciously aware of the fact that the single-handed method was faster than the method he had demonstrated first.

Once he had seen the substantial difference in the times he was convinced of the need to consciously concentrate on the one handed method, which he now teaches to other drivers.

CONCLUSION

Chronocyclegraphy may be regarded as a technique for teaching primarily, and secondarily for contrasting the practical aspects of different types and locations of control levers on agricultural implements. The value will lie as much in the actual time saving benefits as in the psychological effect of the operators knowing that designers have an awareness of the workers' needs.

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(3). They found that high engine speeds rather than load were responsible for the vscosity loss.

SUMMARY

1. Many multi-graded 5W-20 and 10W-30 oils were found to be viscometrically equal to straight graded oils at low shear rates.
2. Multi-graded oils of the 5W-30 designation need to be tested at high shear rates to determine engine cranking characteristics.
3. Pumpability characterstics of 5W-30 oils at 0°F were not equal to 5W and 5W-20 oils.
4. Permanent viscosity loss of 12 to 13 S.U.S. @210° (or 30%) was obtained during sixteen hours of engine operation with a 5W-30 oil.

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