ASIATRIB 2002 International Conference
JEJU ISLAND, KOREA

INFLUENCE OF GEAR OIL FORMULATION ON OIL TEMPERATURE

D. WIENECKE [1] and W. J. BARTZ [2]

[1] *Volkswagenwerk AG, 38436 Wolfsburg, GERMANY*
[2] *Technische Akademie Esslingen, An der Akademie 5, 73760 Ostfildern, GERMANY*

Friction losses in complex tribo-technical system are revealed primarily through their effect on the operating temperature level. In order to assess the influence of the oil formulation on the temperature level comprehensive tests were run in a model test apparatus consisting of a special adapter for the 4-ball test rig. More than ten with different formulations (different base oils, additive packages and viscosity modifiers) were tested. The resulting temperature levels varied by nearly 25 %. The objective of this model testing is to assess the influence of the oil formulation on the operating temperature of vehicle manual transmission. The correlation to the real tribotechnical system was confirmed by a VW Polo transmission test.

1. INTRODUCTION

Friction losses in complex tribo-technical systems primarily result in the operating temperature level. In the course of increasing power density simultaneously with the development of more compact assemblies, e. g. in gears, the temperature level will become more and more important. As it is well known the permanent temperature is characterized by the balance between the originated and the dissipated temperature. Reducing the friction heat eventually will result in the reduction of power losses.

The permanent temperature depends on several influencing factors, especially on the lubricant. It was the aim of the experimental work under discussion to determine the influences of the oil formulation on this temperature. The experiments were performed using a special model test apparatus (a special adapter for the Four-Ball-Machine) as well as a real gear box.

2. MODEL TEST APPARATUS

Because tests with real gears are time consuming and costly a special adapter for the Four-Ball-Machine was developed in order to perform screening tests with gear oil formulations. The test system consists primarily out of an axial grooved ball bearing in a housing made of a material possessing low thermal conductivity.

In order to determine the main influences on the permanent temperature level preliminary tests were carried out. As expected the permanent tem-perature increases with load, speed, viscosity, and oil capacity. All test oils have almost the same viscosity at 100 °C but different viscosity index data. There exists a direct relationship between the viscosity index of the base oils and the permanent temperature. With increasing VI the temperature decreases.

As expected there exists also a linear relationship between the permanent temperature and the viscosity at this temperature. Only the polyglycol, oil C, does not follow this relationship.

After a test running time of about 90 minutes the permanent temperature level is reached. According to these results the test conditions for the main experiments were defined as follows:

Oil capacity	40 ml
(Axial) Load	5000 N
Speed	4000 min^{-1}
Test Time	120 min

These test conditions were maintained constant for all experiments.

The following permanent temperature data represent mean temperatures from 3 single tests. The error of measurement was ± 1.4 %.

3. INFLUENCE OF OIL TYPE AND ADDITIVES ON TEMPERATURE

BASE OIL INFLUENCE – The following 10 oils were selected in order to determine the base oil influence on temperature:

A – Mineral Oil
B – Polyalphaolefin (PAO)
C – Polyglycol (PAG)
D – Diester
E – Polyolester
F – Rape Seed Oil
G – Sun Flower Oil
J – Hydrocrack Oil – 1
K – Hydrocrack Oil – 2
L – Polyinternalolefin (PIO)

The viscosity of all these oils was about 6 mm^2/s at 100 °C but the viscosity index data varied between VI = 108 and VI = 146.

The difference in the permanent temperatures caused by these oils was as high as 22.2 %. The mineral oil A resulted in the highest temperature of 106.7 °C. The lowest temperature was obtained by the polyalphaolefin B with 87.3 °C. All other synthetic base oils, the vegetable oils as well as the hydrocrack oils resulted in permanent temperature between those of the mineral oil A and the PAO B.

Also some mixtures of mineral oil A and the synthetic oils B, D, E and L were prepared and investigated. One can recognize that increasing amounts of mineral oil in every synthetic oils result in increasing permanent temperatures. As expected the mixtures based on PAO B are characterized by the lowest temperatures.

ADDITIVE INFLUENCE – In order to investigate the additive influence on the friction temperature level 7 different additives in a constant concentration of 4 % in the mineral oil A and the PAO B were evaluated. The additives can be characterized as follows:

Additive Package	Elements	Commercially Available
1	P, S	Yes
2	P, S	Yes
3	P, S	Yes
4	P, S	Yes
5	ZnDDP	No
6	P, S	Yes
7	P, S	No

Using the mineral oil A as base oils with the additives 1, 2 and 5 lower temperatures could be realized compared with the base oil alone. With PAO B as base oil all additives caused higher temperature levels than the base oil alone. Additive 5 resulted in the lowest temperature increase. This result could be confirmed using other laboratory test methods too.

4. COMPARING RESULTS OF MODEL TESTS WITH GEAR TESTS

In order to determine the possibility of a correlation of model test results with results obtained in real gears some tests in a real transmission gear were performed. For these tests 5 completely formulated gear oils (oils X1 to X5) were used. As test equipment a VW Polo car with a 1.6 l, 55 kW engine was used. The oil capacity of the gear was 2.7 l. The tests were performed on a dynamometer rig in a wind channel/environmental chamber. The results reveal a good correlation between the model test and the real gear test results.

Compared to these results it could be shown that the permanent temperature depends on the friction force. With increasing friction caused by the different oils the temperature increases too.

5. SUMMARY

The Four-Ball-Machine adaptor especially developed to investigate friction induced temperature levels was proven as a reliable tool to investigate gear oil formulations. Using this test equipment it was possible to evaluate the lubricant formulation related influences on the permanent temperature. It could be shown that the base oil type as well as performance additive packages and VI improvers affect the friction induced temperature level. Formulations based on synthetic oils resulted in lower and those containing VI improvers resulted in higher temperatures. All additive packages intended to reduce wear and scuffing obviously also reduced the friction and by this effect the temperature level.

The test results obtained in laboratory model tests correlated quite well with real gear tests obtained in dynamometer tests.