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LUBRICANTS FOR ROLLING BEARINGS IN REAR AXLE GEARS OF TRUCKS AND DRIVE GEARS OF LOCOMOTIVES[1]

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Abstract

Lubricants for high loaded gears are selected mostly only for the issues of the teeth. The main manufacturers of such gears made specifications for lubricants. The most specification only content a couple of chemical data and some physical data done with model testers like four ball tester, Timken ok, pin on disc or others. In nearly no case there are data related to Rolling Bearings. In spite of data of model testing cannot be transferred to a real rolling bearing. Therefore it is needed to have tests done with rolling bearings to know about performance of lubricants in rolling bearings. Schaeffler Group engineers developed Years ago the FE8 test rig, that can be used to test oils and greases in different bearings types. a wide range of loads and speeds can realize nearly all conditions a bearing can have in the field. In this way also gear oils for rear axle gears can be tested to look to the suitability of these oils in rolling bearings. Schaeffler research tested a couple of different gear oils for use in rolling bearings in high loaded gears at elevated temperatures. Wear protection, fatigue performance, high temperature performance, deposit formation and filterability have been tested. After this Schaeffler selected best oils for use in best bearings. The results will be reported.

Key words: Gear lubrication; Rear axle gears; Rolling bearings.

ESTUDO DE LUBRIFICANTES PARA ROLAMENTOS DO EIXO TRASEIRO DE CAMINHOES E LOCOMOTIVAS.

Resumo

Lubrificantes para engrenagens que operam sob altas cargas são normalmente selecionados com base nos dentes destas engrenagens. Os principais fabricantes destas engrenagens possuem especificações para os lubrificantes, mas a maioria destas especificaões possui somente testes simples como 4-Ball, pino-disco, etc. Em quase nenhum caso há dados relacionados ao rolamentos. Visto que é necessário saber a performance destes lubrificantes nos rolamentos, foi desenvolvida a bancada de teste FE8, que pode ser usada ara simular praticamente todos as condições de operação que um rolamento pode ter. Baseado neste método, alguns óleos de engrenagem foram testados para o uso em engrenagens a alta carga e temperatura. Proteção contra desgaste, fadiga e agressividade química foram testados. Com base nestas informações , os melhores óleos foram descritos.

Palavras-chave: Lubrifição de engrenagens; Eixo traseiro; Rolamentos.

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1 INTRODUCTION

Gear oils are significantly important lubricants as they come into contact with most components of the system. Even though the cost of the lubricant itself is low if compared to other elements of the transmission, the selection of the best oil is of great importance in the design.

The lubrication conditions that characterize the sliding rolling contacts in toothed gears differ from those in roller bearings.

Since, generally, the toothed wheels in a gear have the main requirements on the lubricants, they receive the focus when selecting the oil.

One of the possibilities of explaining the lubricated contacts in rolling bearings is the elastohydrodynamic lubrication, EHL. According to it, as the lubricant gets closer to the contact, the pressure is increased. The increase of the pressure on the oil leads to an increase of the lubricant viscosity, necessary to the establishment of a film at the high pressure contact areas. As the lubricant approaches the the contact, an elastic deformation of the surface is produced due to the high pressure of the lubricant. The closer to the contact, the higher the pressure and, consequently, the higher the viscosity of the oil.(1) The hydrodynamic pressure created is sufficient to separate the surfaces.

Besides the pressure, the viscosity of oils is also highly dependent on temperature. It drops significantly with the increase of temperature, but the rate of this change depends on the type of oil used. The viscosity index (VI) shows how the viscosity changes with temperature, by using the values of viscosity at 40ºC and 100ºC.

Lubricants with low VI have great variations in viscosity when submitted to high temperatures. This can lead to a decrease in film thickness, which can compromise the lubrication of the contact.(2)

At extreme pressures, when the hydrodynamic film is broken, EP (extreme pressure) additives are used. The higher temperature generated in the contact can lead to tribochemical reactions between the metal surface and the components present in the additive, forming a protective layer that will prevent the contact between the surfaces.(3)

Sulfur and phosphorus compounds are widely used to improve EP characteristics of lubricants. Sulfur can be used in inactive and active forms. Inactive sulfur has stable C-S bounds that will react only at higher temperatures. Active forms are much more reactive and can be available at lower temperatures.(2) However, because of this high reactivity, active sulfur carriers can cause damages due to chemical attack on the surfaces. Organic phosphorus compounds work well as an EP/AW additive under certain conditions. Phosphites, besides having good AW properties, also work as a free sulfur scavenger by forming thiophosphates. It is also possible to have additives combining both these elements.(4) Zinc Dialkyldithiophosphate (ZnDDP) is the most important sulfur-phosphorus additive. Besides its AW.EP characteristics are also good antioxidants, which makes it used worldwide.(2)

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2 MATERIALS AND METHODS

Mechanical-dynamical rigs were used to test gear oils. Different conditions were applied in order to emulate possible real lubrication conditions on the bearings.

Several types of gear oils were tested with different compositions and viscosities, covering a wide range of applications, including API GL5. Similar oils with different amounts of additives such as sulfur and phosphorus were used. The oils tested, along with their types, viscosity and additive content are shown on Table 1.

Table 1. List of oils tested with physicochemical information

Oil	Type	Specification	Viscosity	Additive			
				P (%)	S (%)	Zn (%)	Mo (%)
A1	Mineral	CLP	ISO VG 220	0,02	0,06		
A2	Mineral	CLP	ISO VG 100	0,08	0,1		
A3	Mineral	GL 5	SAE 80W90	0,15	1,8		
B1	Mineral	CLP	ISO VG 320	0,1	1,7	0,17	0,03
C1	Synthetic	GL4/GL5	SAE 75W90	0,03	0,07		
E1	Mineral	GL 5	SAE 80W90	0,04	1,8		
E2	Mineral	GL 5	SAE 80W90	0,09	1,7		
E3	Synthetic	CLP	ISO VG 320	0,44	1,07		
E4	Mineral	CLP	ISO VG 320	0,44	1,07		
F1	Synthetic	CLP-E	ISO VG 320	0,015	0,0197		
M1	Synthetic	CLP	ISO VG 320	0,046	3,80E-02		
M3	Synthetic	Cone Driver	ISO VG 320	0,047			
M4	Synthetic	GL 5	SAE 75W90	0,2	2,4		
M5	Synthetic	PM	ISO VG 220	0,08	0,03	0,05	
M6	Synthetic	PM	ISO VG 320	0,07	0,03	0,05	
Q	Mineral	CLP	ISO VG 320	0,078	0,34	0,029	
T1	Synthetic	CLP	ISO VG 320	0,044			0,095
T2	Mineral	CLP	ISO VG 100	0,37	0,5	0,14	0,24
T3	Synthetic	CLP	ISO VG 100	0,308	0,6454	0,23	

The oils shown above were tested in a 3-step program intended to reproduce different friction conditions on the bearings.

The first step aimed determining the effectiveness of the additives on the oil in rolling bearings under extreme mixed-friction conditions by checking its wear protection in a short-term test. The test parameters were the temperature and the cage material. The test was conducted on a FE8 test rig, according to DIN 51891. The tested bearings were 81212 MPB cylindrical roller bearings thrust bearings with brass cage.. The axial load was of 80/100 kN with a P/C of 0.7. The speed used was of 7.5 rpm for 80 hours. The outer ring temperature was 80ºC with a circulating oil volume of 100 cm³/min. Figure 1 shows a schematic of the test rig.

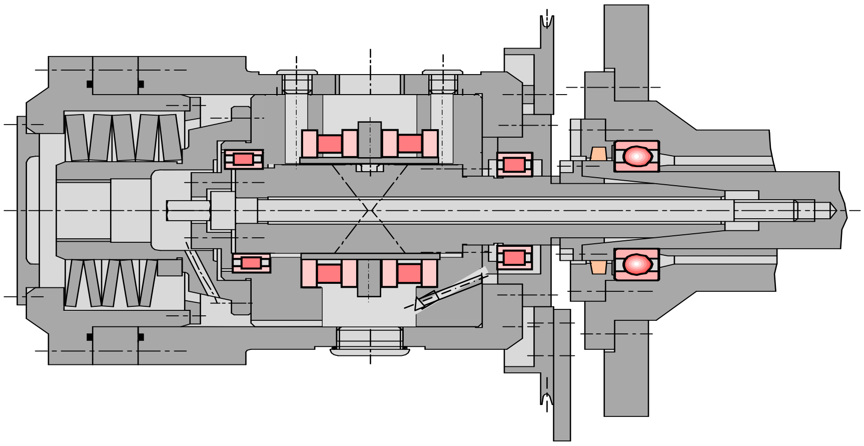

Figure 1. FE8 test rig

The second step was intended to check the effect of the additives in the mixed friction range for long term suitability and also if, beyond the prevention of wear, a sufficient and permanent separation of the surfaces occurs. The long-term tests were run with polyamide cages in order to prevent possible reaction with the brass, up to the fatigue damage or up to maximum twice the L10. The tests were once again conducted on an FE8 test rig according to DIN 51819 with 81212 TVPB cylindrical roller bearings with polyamide cages. The axial load was 100 kN and C/P of 1.27. The speed used was 75 rpm and the l10 is 493h.

The third and final step aimed checking the aggressiveness of the additives in oils under EHL conditions. With complete physical separation of the surfaces by a lubricant film, the effect of the aggressive additive constituents on the surface can be tested. Premature fatigue due to tangential stressing was prevented by a sufficiently thick lubricant film. For this step, the tests were conducted in a L11 test rig with 6206 deep groove ball bearings. The radial load used was of 8.5 kN with a C/P of 1,32. The speed used was 9000 rpm. Schematics of the test rig are shown on Figure 2.

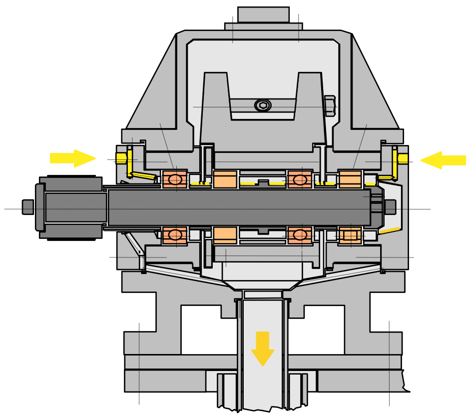

Figure 2. L11 test rig

3 RESULTS AND DISCUSSION

The results obtained on the three steps were plotted. Figure 3 presents the results of the wear of the rolling elements tested according to step 1. Though the data obtained show variations between the performance of the tested oil for

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prevention of wear in bearings, all the oils produced good results, with low values for wear under the tested conditions.

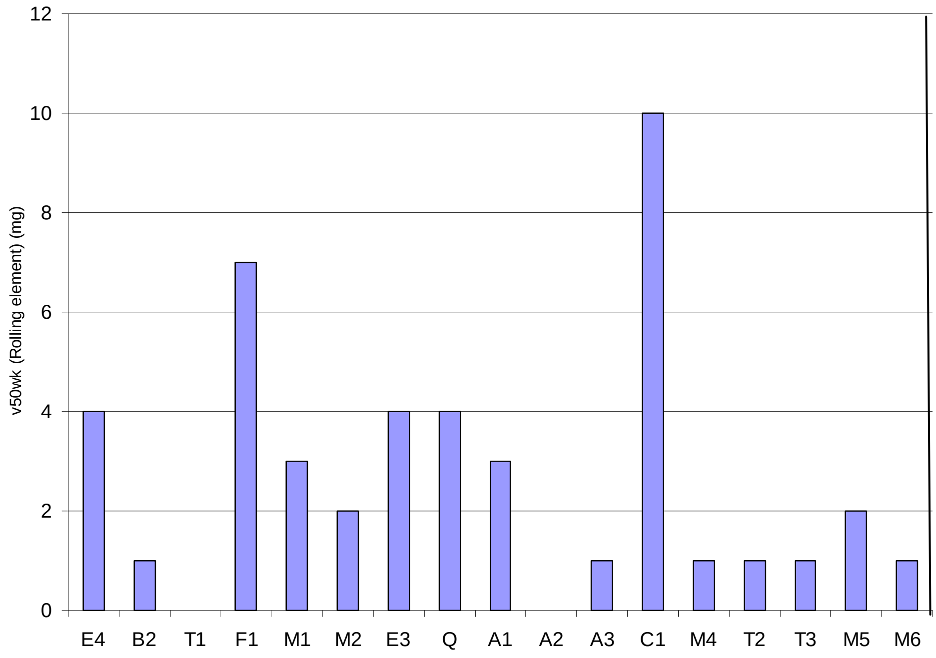

Figure 3. Step 1 – Wear of rolling elements.

Figure 4 shows the weibull distribution for some API GL5 oils. Not all of the oils on the chart have been tested in all steps. Through this chart it is possible to see that some API GL5 oils have very good wear protection while others show poor results in the same tests.

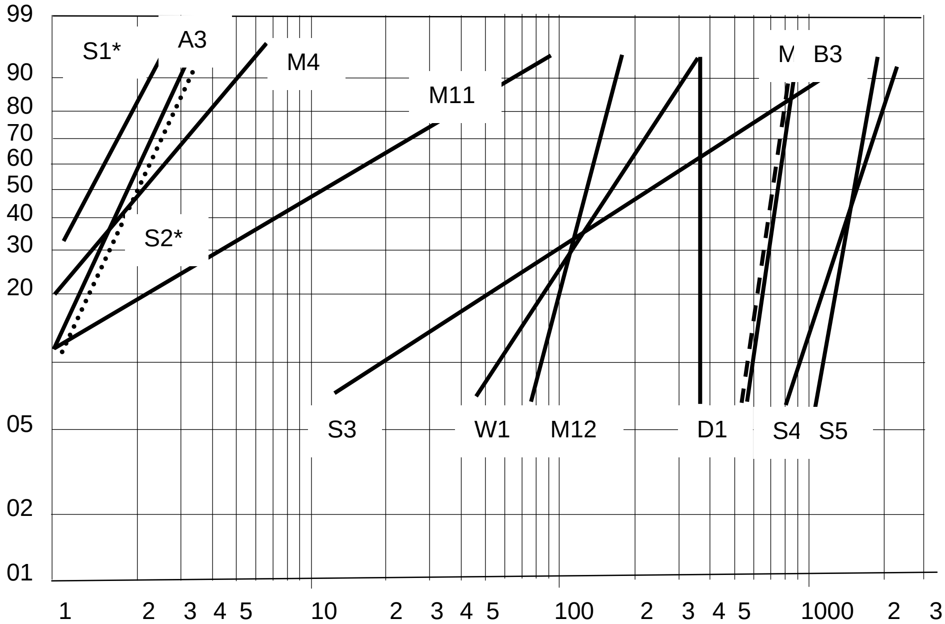

Figure 4. Weibull distribution of FE8 test for GL5 oils.

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Step 2 results are shown on Figure 5. Once again, most of the oils had a very good performance regarding fatigue life. Only one had an earlier failure while all the others reached twice the calculated L10, which guarantees the desired bearing life.

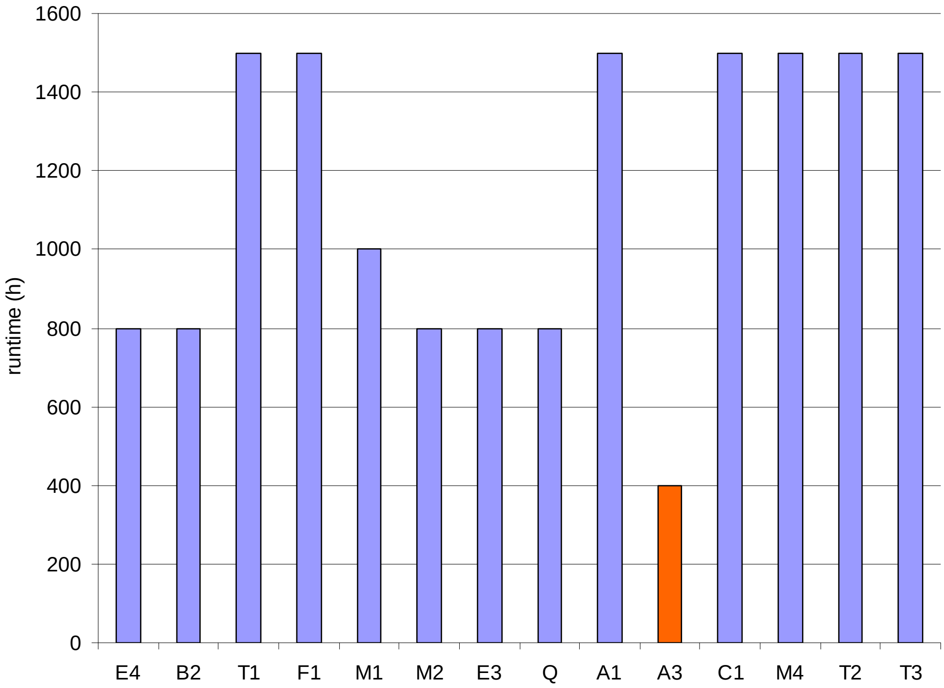

Figure 5. Step 2 – Runtime.

Step 3 allows the study of the aggressiveness of some additives. The high amount of sulfur or other elements can lead to pitting and chemical attacks to the metal surface. Figure 6 shows some SEM pictures of this phenomenon.

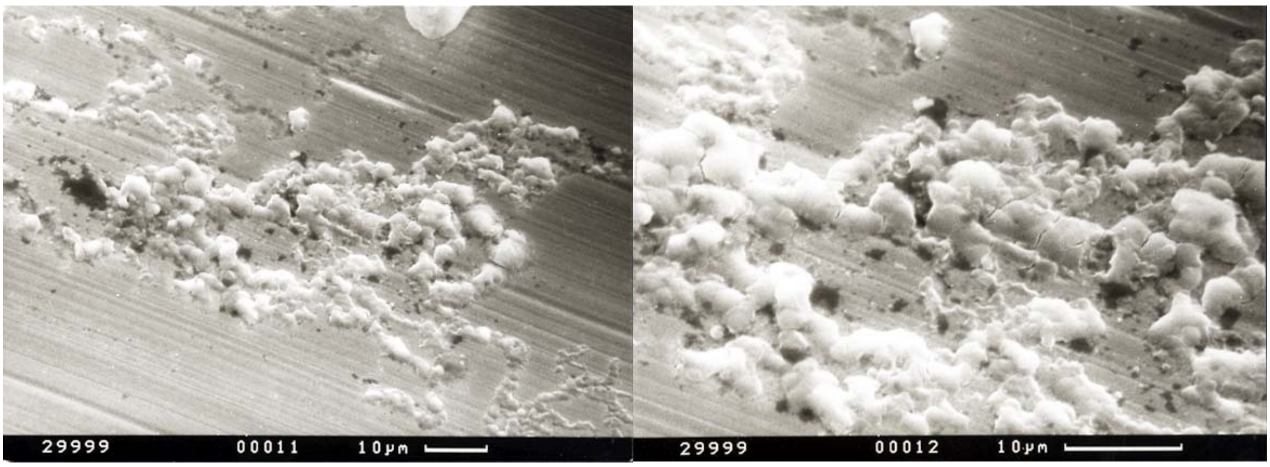

Figure 6. SEM pictures – Corrosive attack.

As it is done under sufficiently simple conditions for the bearings, Step 3 allows the study of the aggressiveness of some additives in the metal surface. Figure 7 shows the results obtained on the L11 rig, under EHL conditions. The test shows that not all the oils tested are successful in preventing this damage. Oils C2 and M, both automotive oils, have additives that are aggressive to the bearing, attacking the metal surface and leading to early failures.

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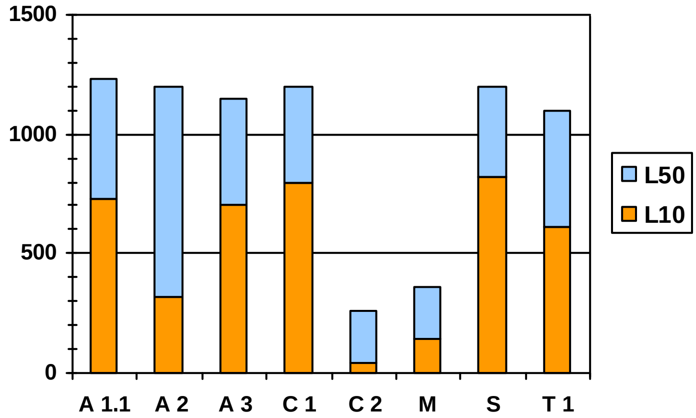

Figure 7. Step 3 Results – Fatigue under EHL conditions.

Next, the results of two types of additives are shown against the requirements of API GL5 gear oils. On Table 2 the results of additive 1 used at 7,5% are presented.

Table 2. Additive 1 results for API GL5 requirements

Base Oil Type				**Exxon**	**Exxon**
Viscosity Grade		**SAE 80W90**	**SAE 85W140**	**SAE 80W90**	**SAE 85W140**
Test Type	Limits				
High Speed Shock Test L-42 Ring Score Pinion Score	Compare with Reference	Pass 16 19	Not Required	Pass 15 18	Not Required
Wear Test L-37 Green Overall Rating	Must Pass	Pass	Not Required	Pass	Not Required
L-37 Lubrited Overall Rating	Must Pass	Pass	Not Required	Pass	Not Required
Moisture Corrosion Test L-33 Rating	2.5 max.	0	0.5	0.5	1.0
Oxidation Stability Test L-60-1 Viscosity Increase, % Pentane Insolubles, % Toluene Insolubles, %	100 max. 3.0 max. 2.0 max.	61.31 1.52 1.19	84.74 1.89 1.25	23.49 0.87 1.08	38.96 0.18 0.23
Copper Corrosion ASTM D130 3 hrs @ 121 °C, rating	2a max.	1a	1a	1b	1a
Foam Stability ASTM D892 Sequence I, ml Sequence II, ml Sequence III, ml	20 max. 50 max. 20 max.	0 0 0	0 0 0	0 0 0	0 0 0

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Also, the results of the same additive tested with the FE8 rig are presented below.

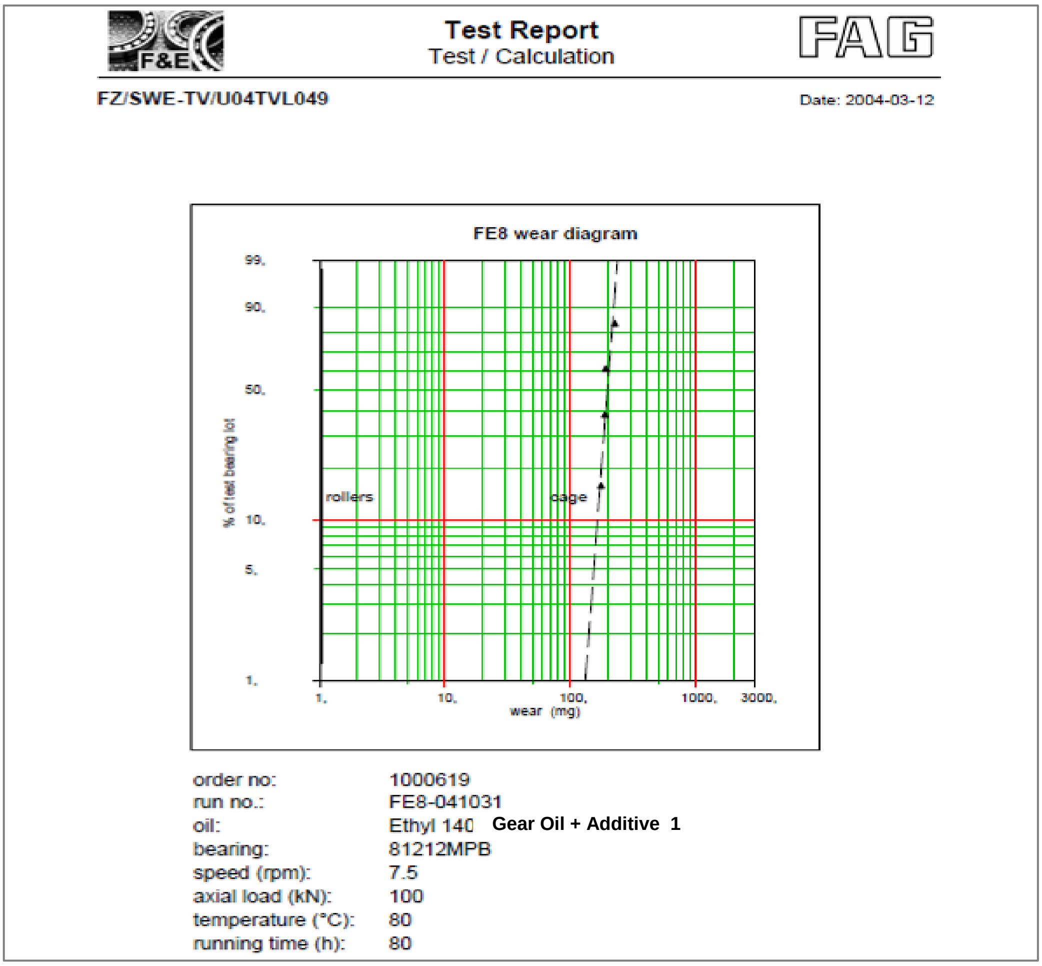

Figure 8. FE8 Gear oil test – additive 1, 7.5%

With these results, it is possible to see that additive 1 is successful in preventing wear on the rolling elements. Also, when used with different base oils of different viscosities, the oils with the additive fulfill the performance requirements of API GL5.

The results for a different additive, 2, used @ 4,4% are shown on Table 3 and Figure 9. Once again, the oil plus the additive performed well on the FE8 test and passed on the GL5 specifications.

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Table 3. Additive 1 results for API GL5 requirements

Test	API GL-5 Requirements	NS/ME 80W90		NS 80W90	
CRC L-33 Corrosion Weighted Rust	Pass	Pass		Pass	
Differential Case	Pinion Contact	0.6		0.6	
	Differential Gear Contact	1.6		1.6	
	Differential Gears (Side)	1.1		1.1	
	Axle Housing Cover	3.06 out of 3.4		3.06 out of 3.4	
	Drive Gear (Ring Gear)	0.5		0.5	
	Drive Pinion	0.5		0.5	
Bearing	Drive Pinion Rollers	0.6		0.6	
	Drive Pinion Cups	0.7		0.7	
	Differential Case Rollers	0.3		0.3	
	Differential Case Cups	0.7		0.7	
Final Rating	9 min.	9.66		9.66	
CRC L-37 Green - Surface Fatigue		**Pinion**	**Ring**	**Pinion**	**Ring**
Burnish	Report	Dull	Dull	Dull	Dull
Wear	5 min.	7	9	9	9
Ridging	8 min.	10	10	10	10
Rippling	8 min.	9	10	10	10
Pitting	3 min*	10	10	10	10
Spalling	10	10	10	10	10
Scoring	10	10	10	10	10
Discolouration	Report	9	9	9	9
Corrosion	Report	10	10	10	10
Numerical		9.79		9.96	
Overall Rating		**Pass**		**Pass**	
CRC L-42 Shock Test	Scoring not to exceed passing reference oil	Pass		Pass	
Ring, % Score		**Candidate**	**RGO-110**	**Candidate**	**RGO-110**
Drive Side		0	0	0	0
Coast Side		13	14	10	25
Pinion, % Score					
Drive Side		0	0	0	0
Coast Side		20	20	14	31
CRC L-60 Oxidation		Pass		Pass	
Viscosity Increase, %	100 max.	26.4		21.37	
Pentane Insolubles	3 max.	0.88		0.39	
Toluene Insolubles	2 max.	0.84		0.36	

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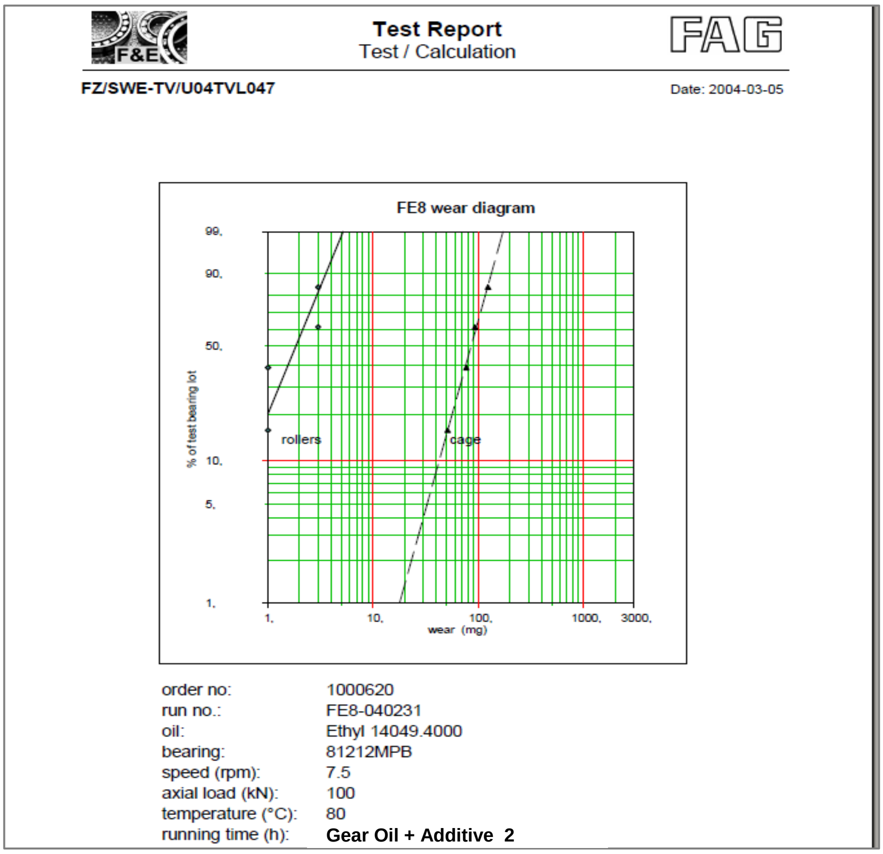

Figure 9. FE8 Gear oil test – additive 2, 4.4%

4 CONCLUSIONS

There are several different requirements for SAE GL5. The main focus of these requirements is the gear performance, as it is possible to see on the specifications. The oils currently used have a wide array of performance in rolling bearings.

GL5 oils have normally high sulfur contents, as these compounds are necessary in the gear lubrication. Nevertheless, sulfur can be harmful to bearings, causing pitting and chemical attacks to the metal surfaces, which may lead to early failures. It is possible, though, to find additives suitable for both parts

Under various test conditions, in which the lubricants were tested as for their performance in bearings, the oils behaved in different ways. Focusing on the GL5 oils, lubricants that were efficient in preventing wear under some conditions, were not so reliable in other tests.

When the right additives were used in the right concentration, effective results for the bearings were obtained and the oils fulfilled the requirements, thus, providing a good alternative for gear lubrication that also takes the bearings into account

REFERENCES

1 HUTCHINS, I. M.; Tribology: Friction and Wear of Engineering Materials, 1992, Great Britaing Editora Edward Arnold.
2 LANSDOWN, A. R.; Lubrication and lubricant selection, 2004, Professional Engineering Publishing Limited
3 MANG, T.; DRESEL, W..; Lubricants and lubricantion, 2007, Wiley – VCH
4 PIRRO, D. M.; WESSOL, A. A.; Lubrication Fundamentals, 2001, Marcel Dekker, Inc.