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SYNTHETIC TRANSMISSION GEAR OIL FIELD TESTING IN LOW-FLOOR TRAMS AIMING TO INCREASE OF OIL CHANGE INTERVAL

Abstract

The development of new gearbox designs, the quality requirements as well as the growing ecology consciousness influenced the development of synthetic transmission gear oils with extended replacement interval.

Monitoring of lubricant operating properties in the application and the analysis of the gained results provide the lubricant replacement at the right time. In this way the costs of lubricant maintenance and supply are reduced, and lubricant manufacturers are able to collect information of the product behaviour in the use which leads to further improvement of the product.

The paper presents the results of application testing of synthetic transmission gear oil in a low–floor tram TIP TMK 2200 which was conducted in order to determine the optimal service interval of lubricants.

1 INTRODUCTION

Lubricating oil in a gearbox is used as a lubrication agent in wide range, in heavy load gearboxes such as gearboxes and differentials of heavy load commercial vehicles and tram reducers.

The development of new gearbox designs, the new quality requirements, as well as the growing ecology consciousness influenced the development of synthetic transmission gear oils with extended replacement interval. All this resulted in reducing the costs of lubricant maintenance and supply. The lubricant manufacturers themselves are getting useful information on the lubricant behaviour in the use which is the basis for further improvement of formulations and determination of the optimal service interval of the lubricant.

2 THE APPLICATION – LUBRICANT TESTING SYSTEM

The gearboxes of low-floor tram Type TMK 2200 were chosen to be the application place for synthetic transmission gear lubricant. There are 6 main and 6 auxilliary side gearboxes (Henschel) in each tram. For the purposes of comparison the field

testing was conducted in two low-floor trams. Drive chassis was equiped with asyncronous electric drive motors without axle between the wheels, which resulted in the 100% low-floor (Fig. 1).

The characteristics of a low-floor tram Type TMK 2200 are shown in the Table 1, and its drive mechanism in the Figure 2.

Figure 1: Low – floor tram

Three step gearbox A (main gearbox) is made of a pair of bevell gears with helicaul teeth and two pairs of spur gears (Fig. 3a). Gear ratio from the shaft axis to the wheel axis is 7,46. The drive shaft is connected to a smaller drive pinion. One part of the torque is transferred from the shaft between the second and third spur gear pairs by the third spur gear pair with intermediate gear to the wheel axle, and another part of the torque is transferred by the horizontal shaft to the auxiliary gearbox B. The gearbox B connects the horizontal shaft with the wheel axle B. One step gearbox B makes a set of gears with intermediate gear with the gear ratio of 3,27 (Fig. 3b). [7]

Table 1: Low – floor tram characteristics, Type TMK 2200 [4], [6]

Manufacturer:	CROTRAM (consortium KONČAR and GREDELJ)
Motor power:	65 kW
Motor speed:	4200 rpm
Number of gearboxes:	12 (6 main + 6 auxiliary)
Vehicle weight:	40 t ± 5%

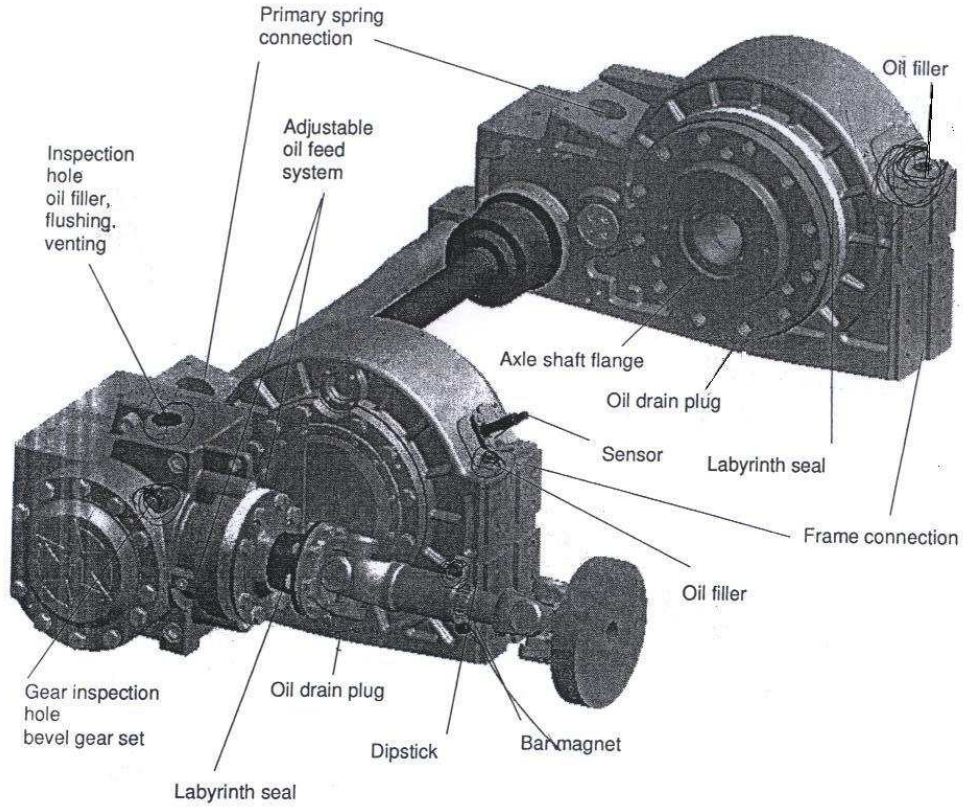

Figure 2: Drive mechanism of low - floor tram [6]

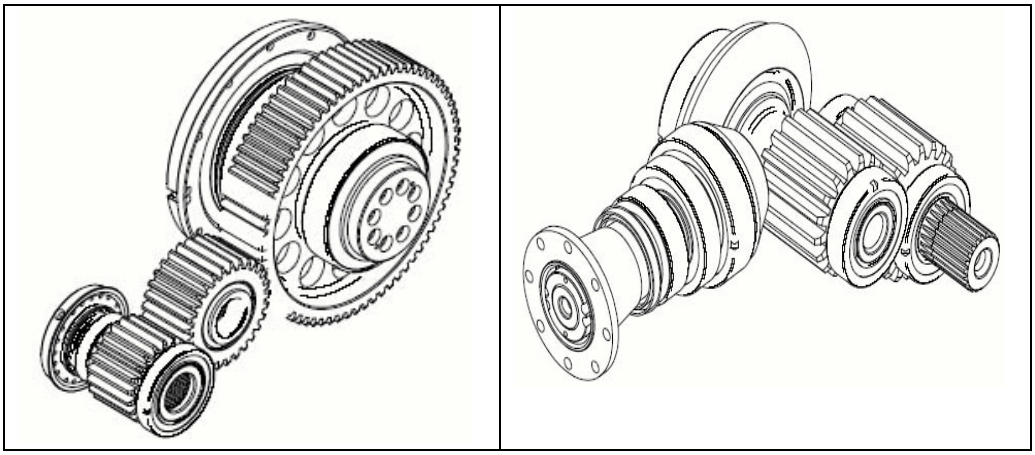

Figure 3(a): Gearbox A

Figure 3(b): Gearbox B

3. LUBRICANT

3.1 General information and lubricant properties

The new vehicle designs with powerful engines have to meet increasingly stringent ecological requirements. The weight of an empty vehicle needs to be as low as possible and with the increased driving performance. These factors influence the load increase in gearboxes. For all these reasons the synthetic gear lubricants with high load carrying capacity, with good oxidation and thermal stability, with corrosion and wear protection and with good low temperature properties are used.

The lubricant with aforementioned properties was used in this field testing. Here we talk about a Croatian lubricant composed on synthetic base oil and carefully chosen additives, which provide for the properties matched to the requirements of new vehicle designs.

3.2. Quality level - specifications

Synthetic transmission gear oil has the following quality level and it complies with the specifications defining the procedures for obtaining the use approval by the original equipment manufacturers (OEM).

SAE 75W-90

API GL-4/GL-5

API MT-1

MIL-PRF-2105E

ZF TE-ML 02B, 05B, 12B, 16F, 17B, 19C, 21B (use approvals)

MAN M 3343 Typ S (use approval)

MAN 341 Typ E3 (use approval)

Mack GO-J

Scania STO 1:0

4. FIELD TESTING

4.1 The aim of the field testing is

- to determine the optimal oil change period for synthetic transmission gear oil
- to observe the lubricant quality during the field testing related to the given acceptability criteria
- to determine the behaviour of commercial synthetic transmission gear oil made in Croatia used in the transmissions of low-floor trams in the conditions of frequent start/stop drive due to stopping at tram stations and general traffic
- to reduce the costs of lubricant supply, storage and vehicle maintenance, which is also connected with the disposal of the used lubricant and packaging

4.2 Sampling schedule

The lubricant samples were taken after 10000, 20000, 30000, 40000, 50000, 60000, 70000 and 80000 kilometers. The field testing is still in progress. For the purposes of the result comparison the field testing was conducted on two low-floor trams Type

TMK 2200. The samples (0,3 l each) were taken from the main and auxiliary gearboxes. The results are shown in the tables for each of the 12 gearboxes (6 main and 6 auxiliary). Single tram covered approximately 1000 km per week, including the planned preventive maintenance. So far the field testing has taken 15 months. For each tram 108 samples were taken (9 samples for each of 12 gearboxes). More than 2200 working hours of the field testing were spent in the laboratory.

4.3 Acceptability criteria for synthetic gear oil SAE grade 75W-90

The limitations given by the equipment manufacturers as well as the earlier experience Croatian oil company experts on the lubricant field testing served as the acceptability criteria for lubricants (Table 2). The final acceptability criteria will be presented at the end of the field testing.

Table 2: Acceptability criteria for lubricant

PROPERTY	TEST METHODS	ACCEPTABILITY CRITERIA
Kinematic viscosity at 100℃, mm^2/s	ISO 3104	± 15 % of original value, at least 13,50 mm^2/s (SAE viscosity grade 90)
Copper corrosion, 3h/120 ℃	ISO 2160	max 2
Acid number, mg KOH/g	ISO 6618	± 50 % of original value
Quantity of iron (Fe), mg/kg	in-house method EDX	max 200
Quantity of lead (Pb), mg/kg	in-house method EDX	max 200

4.4 Implementation of field testing and the results

During the field testing a thorough physical, chemical and mechanical testing for each main and auxiliary gearbox was conducted. The test results were collected in tables and graphically processed. Due to the large amount of information and the size of the field testing only one part of the results for one tram is presented.

Physical, chemical and mechanical properties of fresh lubricant are shown in the Table 3 along with the methods used, and for each property the acceptability criteria have been set (Table 2).

Kinematic viscosity - As one of the most important lubricant properties it represents the rate of internal friction, which works as a resistance to the lubricant molecule position change under shear stress. It depends on the temperature and the pressure. The relation between the viscosity and the density is called the kinematic viscosity. The change of the kinematic viscosity should not be over 15% when compared to the fresh lubricant. For viscosity SAE grade 90, the lower limit is 13,50 mm^2/s. During the field testing the kinematic viscosity was not significantly changed. After the initial decrease it got stabilized and it was within the acceptability criteria.

Table 3: Typical properties of fresh synthetic transmission gear oil

PROPERTY	TEST METHOD	TEST LUBRICANT
Kinematic viscosity at 40℃, mm ^{2}/s	ISO 3104	105,36
Kinematic viscosity at 100℃, mm ^{2}/s	ISO 3104	15,39
Viscosity index	ISO 2909	154
Dynamic viscosity (Brookfield) at -40℃, mPas	ASTM D 2983	65000
Corrosion Cu / 3h/ 120℃	ISO 2592	1a
Acid number, mgKOH/g	ISO 6618	1,46
Quantity of sulphur, %	HRN EN ISO 8754	2,07
Wear scar diameter, mm	ASTM D 4172	0,50
Fe, mg/kg Pb Cr Ni Sn Cu Zn Ba	in-house method (EDX)	< 3 < 3 < 3 4 < 3 < 3 19 < 11
Appearance and colour	visual	clear, brown oil

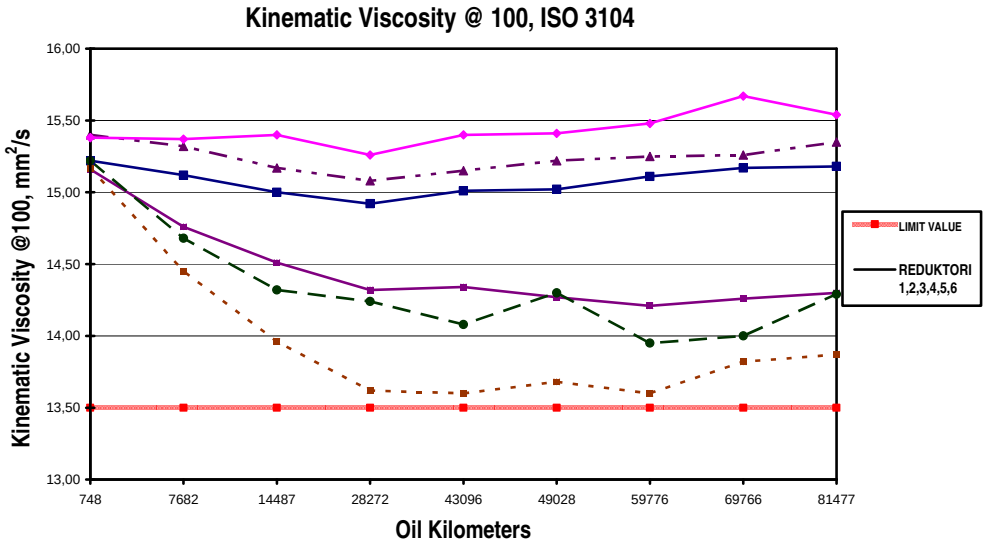

Figure 4: Kinematic viscosity at 100 ℃

Acid number – As an indicator of oil composition has not been significantly changed during the field testing. Its change was less than 20% of the original value. At the beginning there was a slight decrease due to wear of functional additives, and subsequently an increase due to the lubricant oxidation (Fig. 5).

Quantity of metal – Within the field testing the quantity of iron and lead following gear tooth wear was observed. The amount was low, less than 200 mg/kg. It shows that the lubricant has good antiwear properties (Fig. 6). The iron amount of 160 ppm in one sample is a result of unflushed system from the oil that was used before.

The content of heavy metals (Cr, Ni, Cd) was checked by the energy dispersive x ray fluorescence spectrometry (EDX) which showed that their content was low.

Sulphur content – by the sulphur content the lubricant additivity was observed during the field testing. Even after a tram covered 70000 kilometers the additivity was there without any significant decrease during the use.

Wear scar diameter – the samples of lubricant were submitted to the mechanical testing of load carrying properties on 4-ball lubricant testing rig. The system consists of 4 balls, one rotating on 3 fixed placed in the holder, which can be loaded, and filled with the testing oil. The load was standardized (1200 min^{-1}, 392 N, 75 ℃, 1h) during the testing of wear scar diameter. After the testing was conducted, the ball wear diameter was measured. Lubricating film withstanding higher pressures, produces ball welding at higher loading rate and there is less wear. During the field testing there was not any significant increase of wear scar diameter observed when compared to the fresh oil sample (Fig. 7).

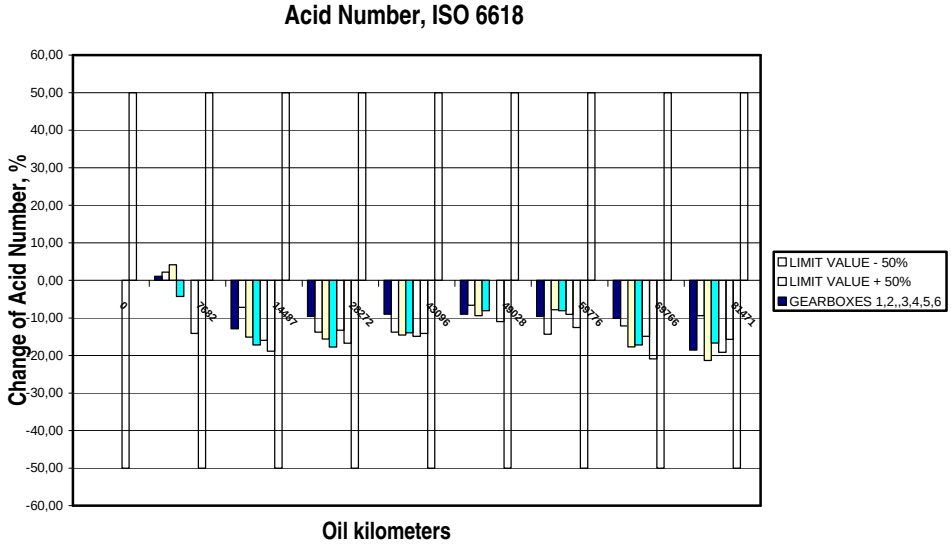

Figure 5: Change of acid number during field testing

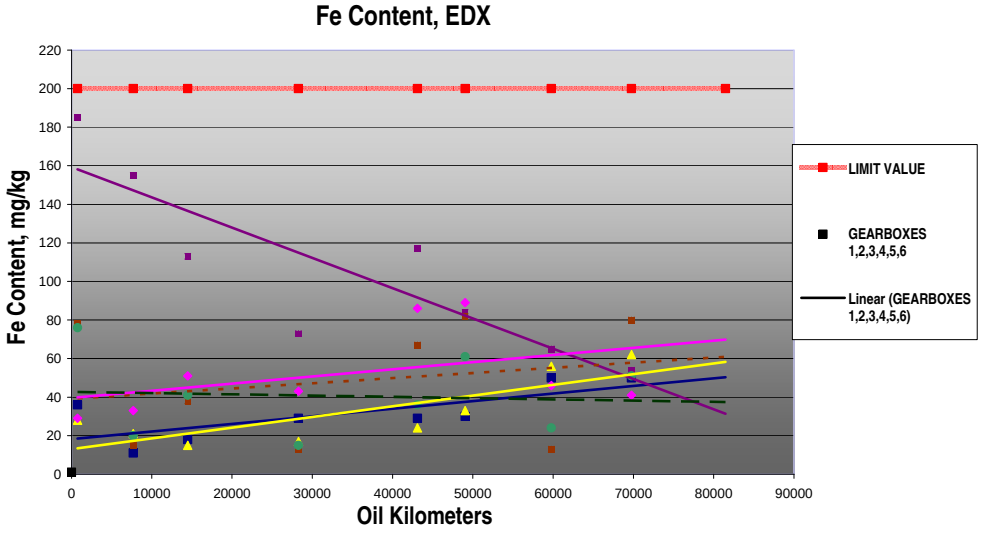

Figure 6: Fe content during field testing

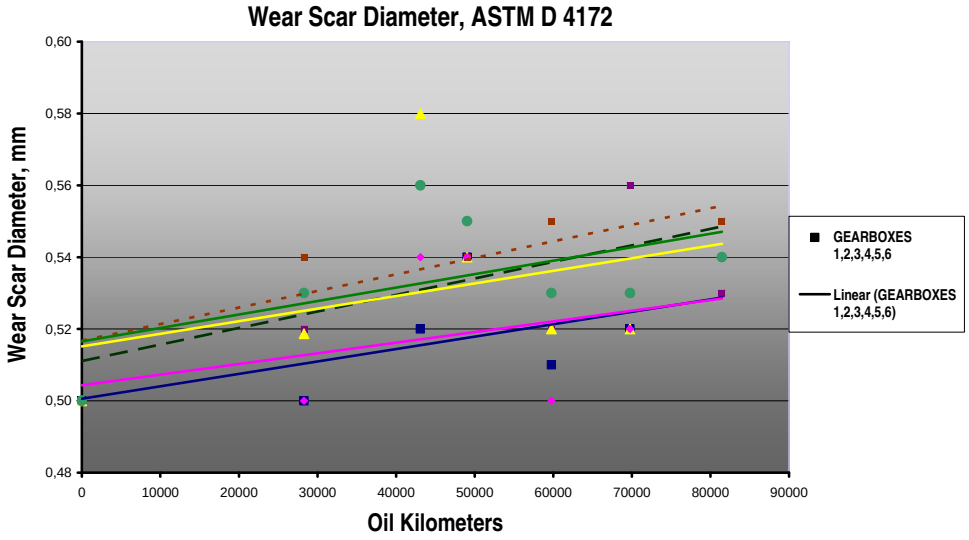

Figure 7: Wear scar diameter during field testing

Within the field testing we also observed the presence of traces of water and mechanical inpurities. At the end of the field testing an amount of in n-petane insolubles was detected from the samples. Low values indicate that this lubricant prevents sludge accumulation and keeps gearbox clean.

The corrosion of Cu on samples had its maximum rate at 1b.

Along with the fresh sample for each gearbox a IR spectrum of lubricant was made. There were only very small changes or no change at all within the spectrum.

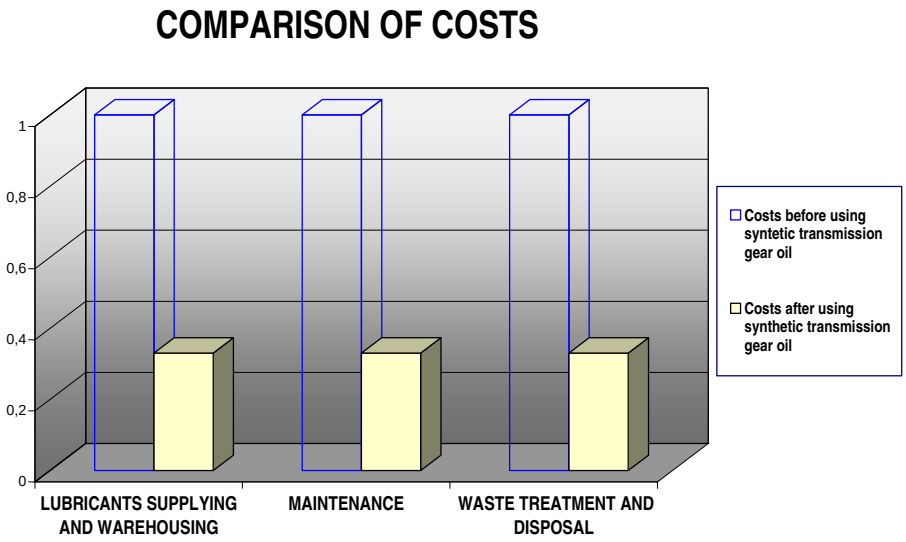

Figure 8: Advantages of using synthetic transmission gear oil

5. CONCLUSION

After the testing of physical, chemical and mechanical properties of lubricants during the field testing and based on the information gained by the final user it can be concluded as follows:

- the tested synthetic transmission gear oil of viscosity SAE grade 75W-90 in low-floor trams kept the basic properties during the field testing
- during the field testing the final user did not have any remarks on the functioning of a low-floor tram as the lubrication was concerned and all the technical requirements of the use were complied
- optimal lubricant change period will be determined at the end of the field testing, by so far the lubricant has been used for over 80000 kilometers
- this kind of field testing provides valuable information on the lubricant behavior

in use and determines the optimal oil change period for lubricant manufacturers and final users

- the costs of lubricant supply, warehousing, transport, maintenance and disposal are up to 70% lower when compared to the lubricant which was used before
- less waste lubricants and their packaging, as well as the extended oil change period, makes this lubricant more ecologically acceptable
- 140 low-floor trams released by the end of 2009 justify the use of this lubricant and stimulates the cooperation of Croatian companies.

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Tehnička dokumentacija Lubrizola.

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620.169.1	vijek trajanja općenito ispitivanje	endurance,durability test in general
625.46	tramvaj	street car
621.833.061	reduktorski priijenosnik	retarder gearbox
621.833.22	stožasti zupčanici s ravnim i helikoidnim zupcima	bevel gears with straight and helical teeth
621.833.1	čelnički par zupčanika	spur gears
.004.58	održavanje, proaktivno, praćenjem stanja maziva	maintenance, proactive, lubricant condition based
.004.53	održavanje, preventivno, po terminskom planu zamjena	maintenance, preventive, time scheduled
.004.18	gledište uštede pri uporabi, primjeni i radu	savings in use, application and operation

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