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POSSIBILITIES OF EXTENSION OF GEAR OIL SERVICE LIFE IN RAIL VEHICLES

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Abstract

The study deals with the results of operational tests of gear oils used in a regional railway transport system. The character of the aging process and the impact of gear oil operation on the main factors determining further usability of gear oil have been defined on the basis of the results of carried out tests. It was proved that transport systems lack reliable convenient diagnostic methods for gear oil used during the process of operation. One of the criteria taken into consideration in decision-making is the period of oil change imposed by the gear manufacturer. The long process of oil application is accompanied by physicochemical changes, which cause degradation of its properties. This phenomenon is referred to as oil aging. This fact can cause loss of viscosity, increase in the amount of pollution, and in effect a decrease in the ability to provide a durable boundary film. The lubricating ability of oil decreases as well. An increase in the amount of pollution is caused by interaction of the collaborating friction elements and by pollutants coming from the gear environment. These changes are of permanent character and reflect the state of new characteristics referred to as operational characteristics. Gear oils have a certain lubricating ability, which is a critical parameter. This study is an attempt to find a way of the oil service life extension and convince the propulsion systems manufacturers that reduction of costs connected with rail vehicle maintenance does make sense.

Keywords: *transport, rail vehicle, lubricity, ignition temperature, concentration of wear products, kinematic viscosity*

1. Introduction

The process of oil operation is accompanied by physicochemical processes, which cause changes in the oil lubrication ability. Changes in the lubricants occur due to interaction of the system elements and the materials. These changes are of permanent character and reflect occurrence of new operational characteristics [3, 4]. Degradation properties of oil determine its serviceability.

Appropriate operation of friction nodes in a gear, such as: working surfaces of a gear and slide bearings – journal – bearing, determines technical efficiency of the gear and depends on the quality of lubricants (oils) and the amount of pollution generated in the gear that get to the oil [6].

Specificity of gear oil pollution involves its constant accumulation as the gear lubrication systems are closed circulation systems. Intensity of gear oil pollution depends on the following factors:

- technical state and service conditions of a gear,
- type and state of the oil filtration system,
- type of sealing,
- type and state of the gear chamber air filtration system.

Technological progress in base oils manufacturing and packets of refining additives will enable production of gear oils with high viscosity index [1, 2]. Gear oils with specified kinematic viscosity, characterized by high viscosity index, provide viscosity that allows them to be pumped to ensure good mobility properties of the lubrication system and in the operational temperature; they provide adequate durability of the oil film, which in turn, guarantees appropriate lubrication of the gear friction nodes.

Along with the development of high performance gears, gear oils need to meet higher qualitative requirements while ensuring maintenance of ecological norms. The values of fresh oil parameters can vary considerably from the values of service oils. The major physicochemical and functional properties are identified in laboratories with the use of standard methods. Now, there is a wide variety of research methods and the most modern one is Brookfield scanning method related to the new criterion of oil pumping ability assessment [7].

Development of railway transport and subsequent modernizations of rail tracks make it possible for rail vehicles to reach higher speeds. So far, the speed limit of trains was 120 km/h on most of the train routes in Poland. Nowadays, this limit has been increased to 160 km/h. Significant increase in the speed limit for trains contributes to an increase in the propulsion system loading, both for the combustion engine and traction drive systems [5].

2. Research goal

The research goal is to identify the possibilities of gear oil service life extension in order to optimize operation costs of rail vehicles used in regional passenger train transport.

3. Research object and subject

Gear oils BP ENERGEAR SHX LS 75W90, used in traction drive systems of passenger trains have been investigated. They are fully synthetic oils used in hypoid gears with a limited slip system. Gear oils of Limited Slip type with a special friction modifier, find application in gears transmitting significant torques. They provide Limit-Slip gears with maximal protection and optimal lubrication.

The research subject is processes that occur in gear oils during their operation. The capacity of the considered multi-degree gears lubrication systems are 76 litres. The basic values are presented in Tab. 1.

4. Research method

Oil specimens were collected directly from the oil bowl of gears of vehicles through oil inlets by means of a syringe connected with a hose.

According to the documents of the considered transport system maintenance department, gear oil needs to be changed every 1500 hours of operation. Tests were performed until reaching 2800 hours of work.

Oils from four gears, installed in two rail vehicles with similar operational potential, were taken for tests. It needs to be mentioned that all gears were equipped with a system of the chamber air filtration. The gears whose oils were tested interacted with 390 kW power engines.

Tab. 1. Basic physicochemical parameters of BP ENERGEAR SHX LS 75W90 oil [manufacturer's details]

Oil BP ENERGEAR SHX LS 75W90	Research method	Unit	Parameter value
Viscosity class SAE			75W90
Kinematic viscosity in 100ºC	ASTM D 445-97	mm^2/s	15.5
Kinematic viscosity in 40ºC	ASTM D 445-97	mm^2/s	102.7
Viscosity index	ASTM D 2270		160
Brookfield viscosity in -40ºC	ASTM D 2983	mPa s	139 000
Quality class API			GL-5
Ignition temperature COC	ASTM D 92	ºC	210
Flow temperature min.	ASTM D 97	ºC	-54
Density in temperature 15ºC	ASTM D1298	kg/m^3	859

5. Tests results

Tests results of concentration of wear products of tribological nodes are presented in a graphical form in order to better reflect the changes of values.

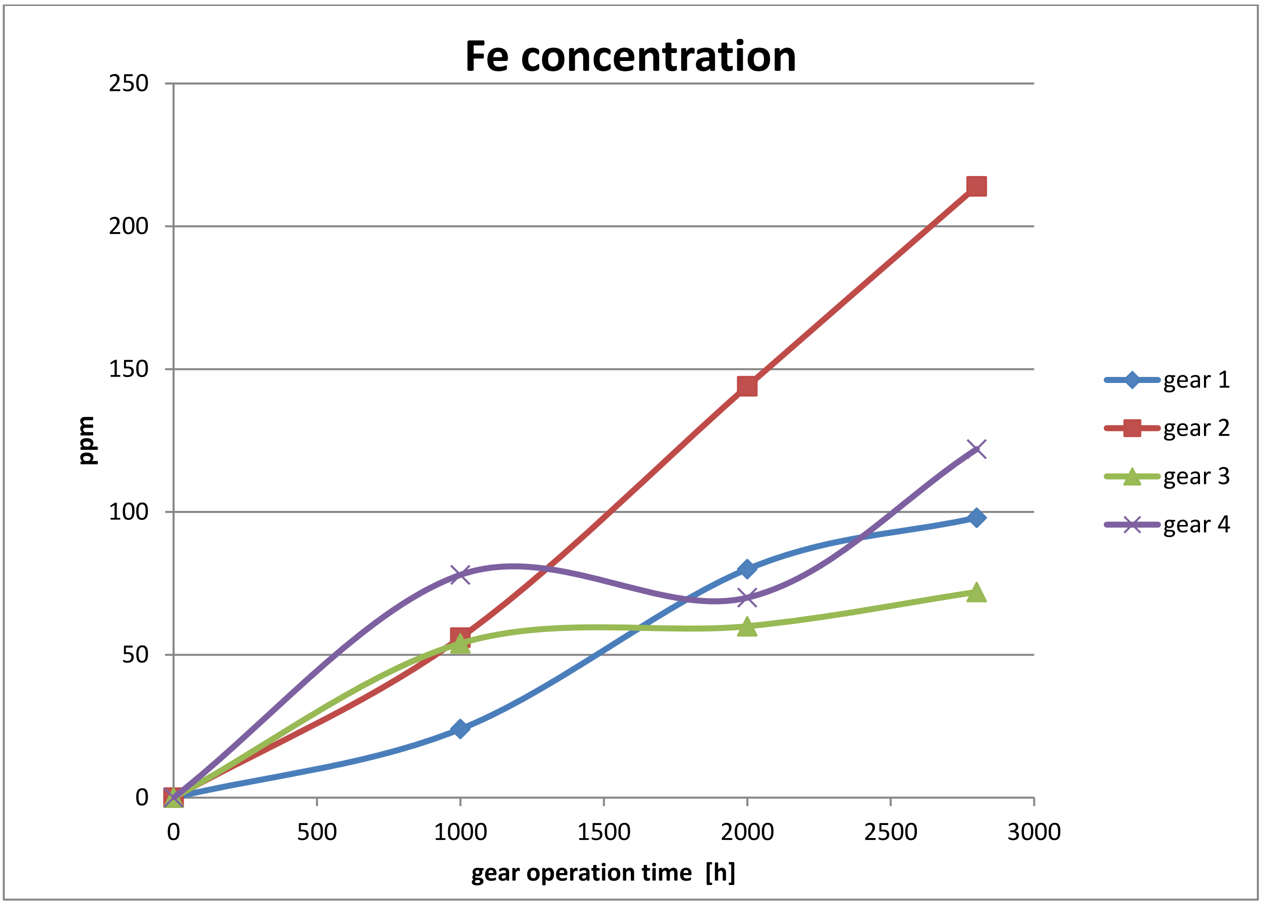

Fig. 1. Changes in iron concentration depending on the number of hours of the gear operation

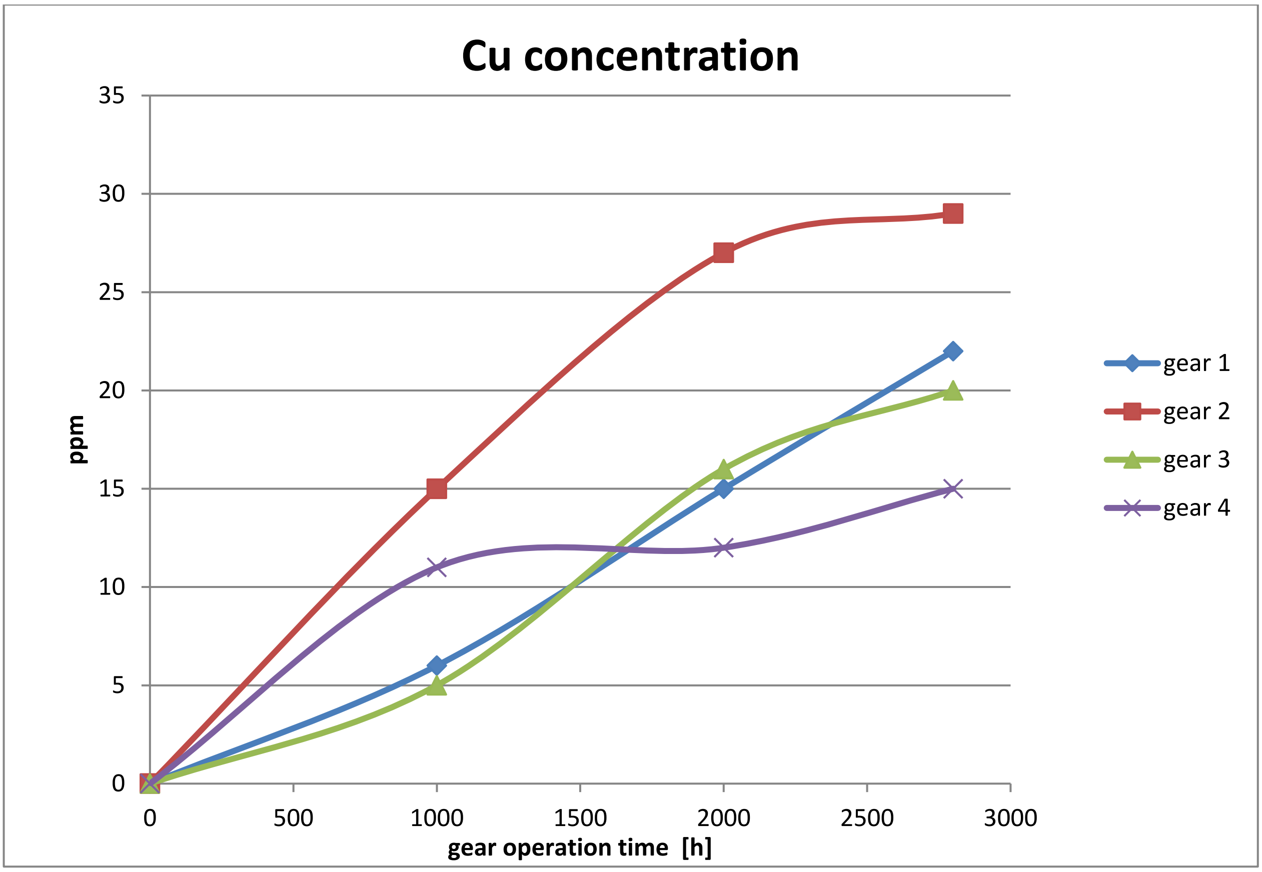

Fig. 2. Changes in copper concentration in oil depending on the number of the gear operation hours

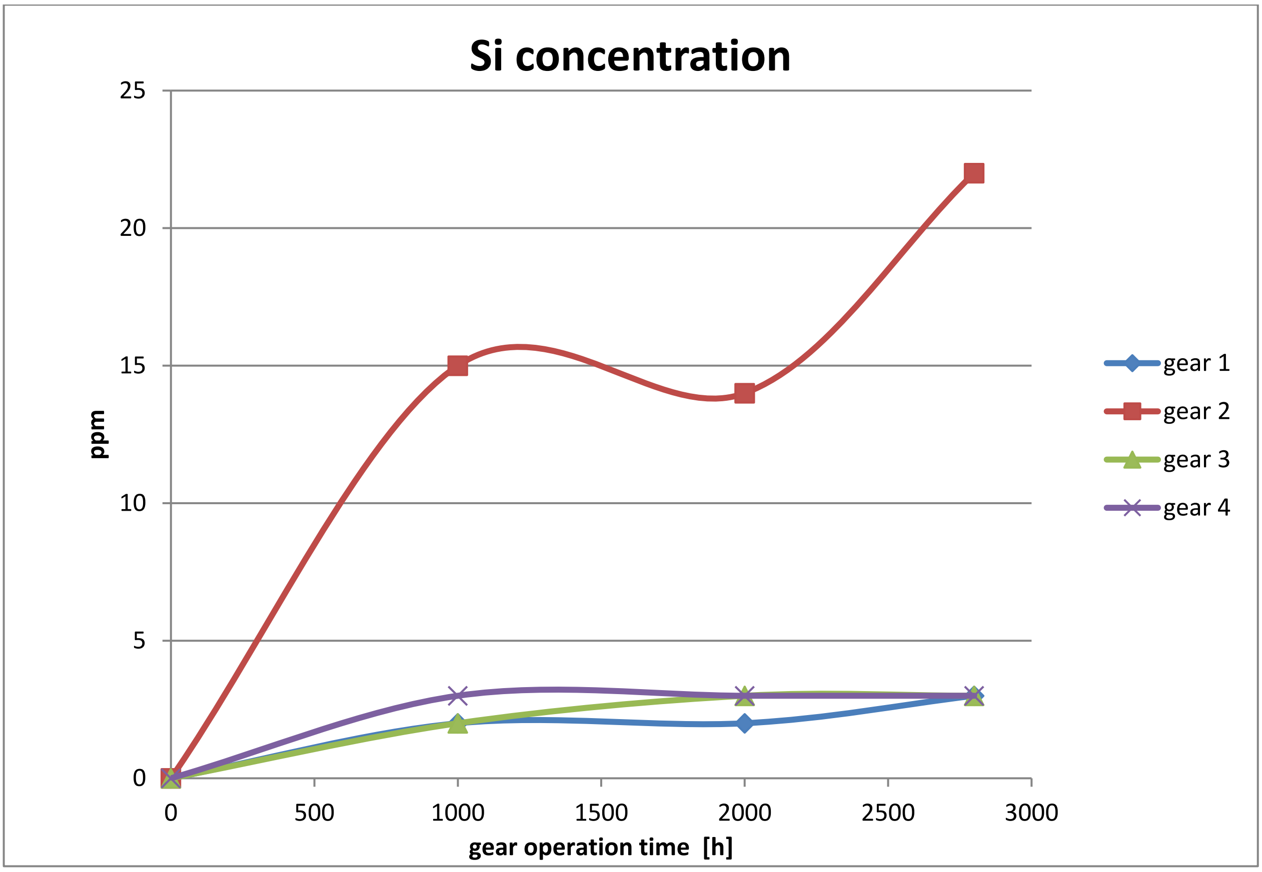

Fig. 3. Changes in silicon concentration in oil depending on the number of the gear operation hours

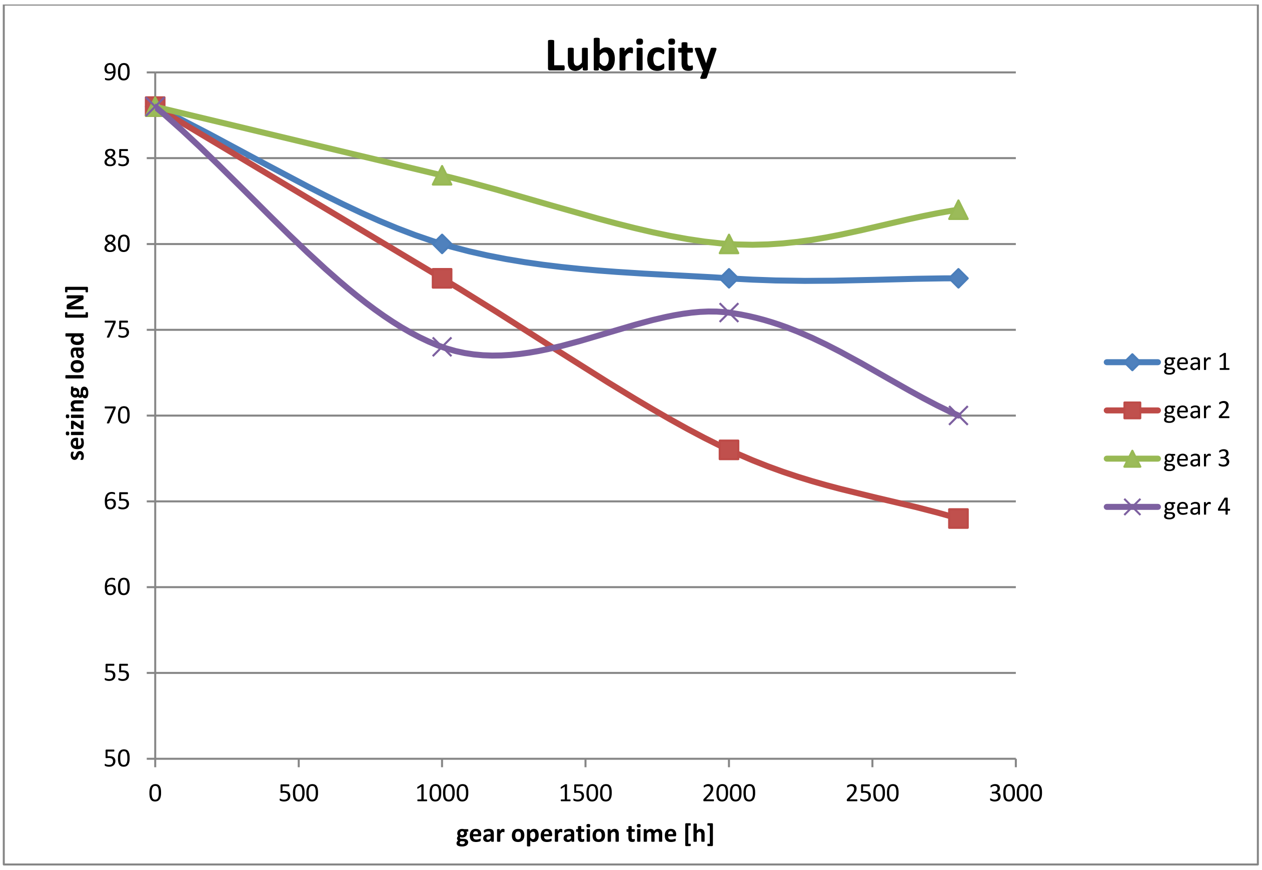

Fig. 4. Changes in lubricity of oil depending on the number of the gear operation hours

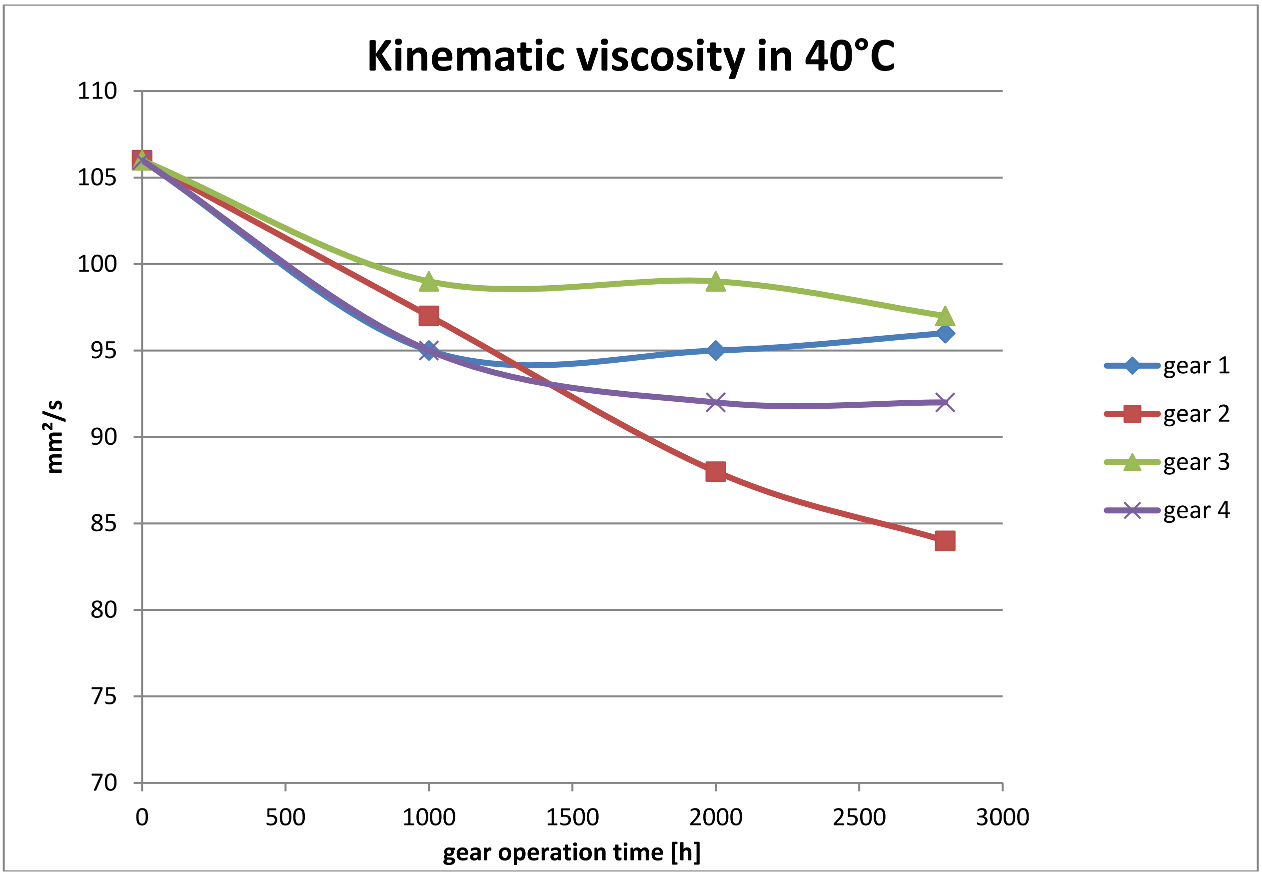

Fig. 5. Changes in kinematic viscosity in 40ºC depending on the number of the gear operation hours

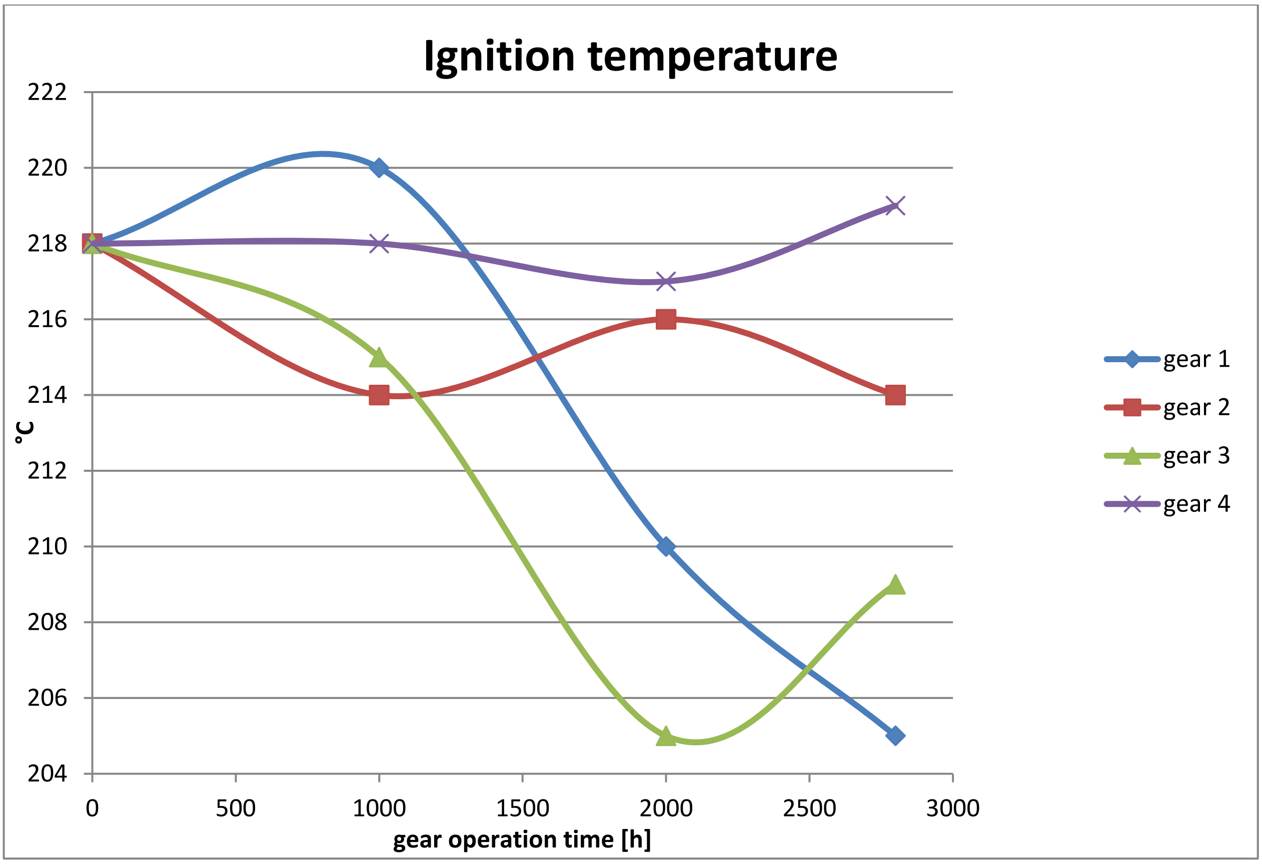

Fig. 6. Temperature changes of oil ignition depending on the number of the rear operation hours

6. Analysis of the results

Figure 1 and 2 show the concentration dependences two metallic elements in the tested oils. In the tested specimens of gears, 1 and 3 there was no sudden change found for concentration of metallic elements, which can be a proof that there is no accelerated wear of tribological nodes due to unserviceability states. Increase in iron concentration occurs almost in a linear manner and reaches the maximum value below 100 ppm. Manufacturer of gears recommends that the value should not exceed 120 ppm. In addition, concentration of copper in gears 1, 3 and 4 remains at an acceptable level and finally, after 2800 hours of operation, it reaches barely 20 ppm. The above results prove that anti-wear properties of oil in these gears still remain at a very high level. Analysing a relatively low concentration of metallic elements, directly reflecting the wear of tribological nodes, it should be assumed that lubrication properties of gear oil stabilize after reaching the assumed service life while maintaining appropriate dispersing – washing abilities of oil. A different situation was found for gear two. The rate of iron and copper concentration increase is high and at the end of the tests, the levels of these elements were, respectively: above 200 ppm for iron, 28 ppm for copper. The manufacturer’s maximum, permitted level of iron particle content was exceeded at the time of fixed service life.

Figure 3 shows changes in silicon concentration depending on the gear operation time. Silicon concentration changes have been presented in dependence on the gear operation time. A slow increase in silicon concentration in gears 1 and 3, 4 means that the condition of the labyrinth sealing system is good, and the oil and air system of the gear box works correctly.
The oil from gear 2 exhibits cascade increase in silicon concentration

Figure 4 shows changes in the parameter of lubrication ability of the tested oils. Tests of the oil boundary film – lubrication ability, were performed with the use of Timken device by measuring seizing load [6]. The figure shows that after initial drop in lubricity, the value the of lubrication parameter stabilizes at the level about 80 N for gear 1 and 3. For gear 4, the lubricity ranges within 75 N to drop down to 70 N at the end of the tests.

Lubricity of gear No. 2 remains a constant falling tendency from the initial level for fresh oil 88 N, to 64 N at the end of tests, after 2800 of operation hours.

Figure 5 shows changes in kinematic viscosity of the tested oils, depending on the gear operation time, from the last oil change. In oils of gear 1 and 3, as well as 4, viscosity slightly changed along with the operation time to eventually stabilize, after about 1000 hours of work, at the level of 95 mm^2/s. Viscosity of oil of gear 2 was found to have lost viscosity down to the level of 84 mm^2/s. The course of kinematic viscosity changes in this gear was almost linear. It needs to be noted that the manufacturer recommends that the viscosity oil ranged within 90-115 mm^2/s.

Ignition temperature was additionally measured in an open crucible during the tests by means of Clevland method. In the oils of gear 1 and 4, the ignition temperature value exhibited slight variability, the ignition temperature of oils of gear and 3 were found to have dropped down to the level 205ºC.

7. Conclusions

Tests of gear oils used in buses operated in a transport system such as Regional Railways allow providing the following conclusions regarding safety of gear oil service life extension: there is a close relation between changes in the oil physicochemical properties and mileage of the vehicles. It has been proven for 3 gears, on the basis of the obtained tests results, that for the level of loads caused by external factors, the basic physicochemical properties do not undergo changes to the degree indicating the need to change oil. One of the gears exhibited an increased amount of silicon particles, which could cause accelerated wear of the friction nodes. In result of silicon penetration inside the gear, increased amount of metallic contamination in was found in the oil. The tests results have confirmed advisability of gear oil service life extension by even by 50% while ensuring monitoring the content of solid particles.

Service life of oil used in a gear with seals of appropriate quality and gearbox air filtration can safely be extended.

The tests have revealed that the concentration of wear products accumulating in oil includes diagnostic information. Systematic checks of the value of the most important parameters determining the oil usability state makes it possible to determine boundary sates, for which the oils stops fulfilling its function in the tribological system, such as a gear.

Extension of the periods between gear oil changes enables significant reduction of technical objects (rail vehicles) operation costs. Due to potential effects of gear failures and costs of their removals, operators of rain vehicles, who are often their owners, are not willing to take the risk involved in the research on gear oil service life extension with the use of vehicles providing transport services in transport systems.

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