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THE POSSIBILITY OF MODIFYING THE LUBRICITY OF TRANSMISSION OILS IN INDUSTRIAL GEARS

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Abstract

The study deals with the issue of durability extension of multi-phase gears working under temporary or constant loading. The tests were performed for transmission oils used in power transmission systems of beet washers of DC type used in sugar plants. The lubricity parameters of oils and the possibilities of their modification through introduction of low-friction additives to the oil were studied. Additionally, the noise level emitted by working gears was measured before and after addition of the modifier. Lubricity tests were performed on semi-Timken apparatus, on which friction pairs friction roller- roller were tested with the use of oils extracted from the gear. SoundMeter application with MIC002 microphone adaptor was used for measurement of the noise level emission. Tests results have confirmed efficiency of the modifiers as higher values of friction loading were obtained and the noise emission level was reduced. It has been proven that in real operation systems, there is a possibility to increase the value of transmission oil lubricity parameters, which has a direct impact on durability of friction pairs of a gear during its operation.

Keywords: *lubricating oils, gear box, friction, lubrication, boundary layer, low friction additives, acoustic emission*

1. Introduction

Limited time of a raw material processing preferred in sugar industry is caused by a short period of its fitness for use, that is, change in its technological parameters and sucrose distribution as well as loss of sucrose over time. Therefore, a tendency to increase the norms for daily outputs of particular sugar plants can be observed.

Nowadays, some sugar plants in Poland process over two times more of nominal daily outputs. For example, at the end of the 90s, a medium size sugar plant processed nearly 240 tons of beetroots daily, whereas, now it processes 5000 tons.

Naturally, such a plant needs to be significantly modernized in order to be able to provide so increased product output. All the departments, along with their equipment, have been rebuilt to increase the production efficiency. However, there are devices whose nominal loads are arbitrarily increased even by 150% without improving their main structural characteristics. This group includes beet washers of DC type. These devices have been produced since the beginning of the sixties, installed in sugar plants, which have been working until today with no intervention in their main structural, technological or geometric characteristics. While increasing their daily output capacity the systems of power transmission have not been significantly modernized.

In a beet extractor, power is transmitted from electric motors through a set of reduction gears. Each propulsion system includes a multi-phase gear lubricated by a circulating transmission oil. These gears work under full loads, transmitting maximal permissible torque values. Momentary overloads exceeding the range of permitted loads can cause occurrence of undesirable phenomena, such as dry friction and occasionally pitting or spalling. Momentary overloads are accompanied by an increase in noise and vibration emission coming from the gear working elements. In result of these cyclically repeating overloads, accelerated wear of the gear and even emergency damage can occur.

Along with the development of power transmission by means of gears, a demand for high quality oils has increased which meet an array of criteria, including: kinematic viscosity, lubricity, pumping ability, resistance to foaming, stability, corrosion inhibitor content, dispersing washing properties and many others. A s far as the above mentioned characteristics of oils are concerned, this is lubricity which is of critical importance from the point of view of a gear durability – expressed as the ability to maintain the boundary layer separating friction pairs.

Lubricity of mineral transmission oils and thus durability of the boundary layer can be modified by means of different low-friction additives. Literature provides numerous studies regarding modification of engine oils [1-3, 5] and gear oils used in small gears [4, 6-8]. According to the author [4], it is not recommended to modify synthetic lubricating oils with additives due to the risk of occurrence of antagonisms between added to oil modifiers and chemical compounds, which are ingredients of high quality synthetic oils.

In all the cited works, modification of a lubricating agent does have a positive influence on tribological properties of the friction coupling. Tests were performed on a four ball apparatus; noise emission was not tested.

2. Research goal

During a long-term process of an oil use, it undergoes physical-chemical changes, which cause degradation of its properties. This phenomenon is referred to as oil aging during service. This fact can cause loss of viscosity value, contamination increase and in effect, limitation of the ability to provide a durable boundary film. Lubricity reduction follows. These changes occur in transmission oils due to interaction of the friction pair elements as well as in effect of contamination coming from the gear environment. They are of permanent character and reflect occurrence of new characteristics referred to as functional properties. In the case of gear oils, we have to do with a certain value of lubricity, which is a critical parameter. Low quality of the mineral oil boundary film can result in accelerated wear of the gear friction pairs.

The aim of the tests is to define the possibility of increasing the oil lubricity with application of synthetic low-friction additives on the basis of sulfonates and alkyl chlorides.

The general goal of this study is to improve the quality of multi-phase gears.

An additional goal is to find out the relation between the gear oil lubricity parameter and the gear noise emission level.

3. Research subject and object

Gear oils Transol 220, used in multi-phase, angle-roller gears of Zamech BWR304 type with power 250 kW were tested. Nominal amount of oil in each gear is 167 litres. Gears are equipped with a system of circulating oil lubrication. The oil circulation is induced by a pump with an adequate electric drive installed on each external gear. The system of chamber ventilation is equipped with a dust filter to reduce penetration of contamination to inside the gear. The source of contamination accumulating in the transmission oil can be friction pairs of the collaborating metal surfaces.

The research subject is to determine durability of the transmission oil boundary film during its service and a possibility of this parameter modification.

The nominal values of Transol 220 oil parameters are presented in Tab. 1. Before introduction of low friction additives into the oil, specimens were extracted to be tested for selected physico-chemical parameters. In order to compare the values of selected physicochemical parameters declared by the manufacturer, specimens of fresh oil were provided as well.

Tab. 1. Physicochemical parameters of Transol 220 oil

No.	Parameter	Unit	Typical values
1.	Kinematic viscosity in 100ºC	mm^2/s	18.8
2.	Kinematic viscosity in 40ºC	mm^2/s	220
3.	Viscosity index	–	86
4.	Flow temperature	ºC	-18
5.	Ignition Temperature	ºC	215
6.	Corrosive action in the copper plate, 3h/120ºC, corrosion degree	patterns	1b
7.	Resistance to emulsification, time of the water-oil emulsion delamination	min	30
8.	Lubrication properties – wear index under loading (I_h)	daN	40
9.	Lubrication properties – load of welding (P_z)	kN	2,15
10.	Ability to transmit loads on the FZG station, degree of damaging loading, not lower than s	–	10

Low friction additives to oils can be divided into conventional additives containing solid lubricants with layer structure (such as graphite, molybdenum disulphide, boron nitride), nano-particles of soft metals and technologically advanced synthetic low friction additives.

Modification of the boundary film durability value was applied by using two concentrations of low friction additives:
- 2% of Metaltec 1213,
- 4% of Metaltec 1213.

Metaltec 1213 is a synthetic carbohydrate complex containing compounds actively modifying the friction surfaces. Metaltec 1213 contains sulphur and chlorine compounds.

Oils from four gears working in parallel diffusers of DC type, on one beet extraction line, were tested. Each diffuser is propelled by a friction pair of the same type. The gears operate under similar loading and in the same hall of the beet juice extraction and processing plant. All the gears are characterized by a similar level of operating potential. Fig. 1 shows the above-described gears.

Tests of the boundary films of oils were performed by means of a semi-Timken apparatus. It is a device used for tests of lubricating agents based on the operation principle of Timken apparatus. Apart from, insignificant from the point of view of this study, construction details of the semi-Timken device differ from Timken apparatus by the type of the initial contact of the specimen and the counter specimen. In Timken apparatus the specimen – a block in the shape of a cuboid, is undergoes galling on the external part of the ring roller – counter specimen. In semi-Timken apparatus, the specimen has a shape of a roller and undergoes galling on the ring as well. The initial contact of the specimen with the counter specimen in Timken apparatus is linear, whereas in semi-Timken – is of point character. Differences between the associations of friction pairs of the specimen and the counter specimen are presented schematically in Fig. 2. The initial point contact of the associated friction pair allows using smaller pressures to be exerted on the specimen during tests. The friction association of semi-Timken apparatus makes it possible to exclude the error of non-parallelism of the ring to the roller surface. Such an error can occur in friction pairs of Timken apparatus.

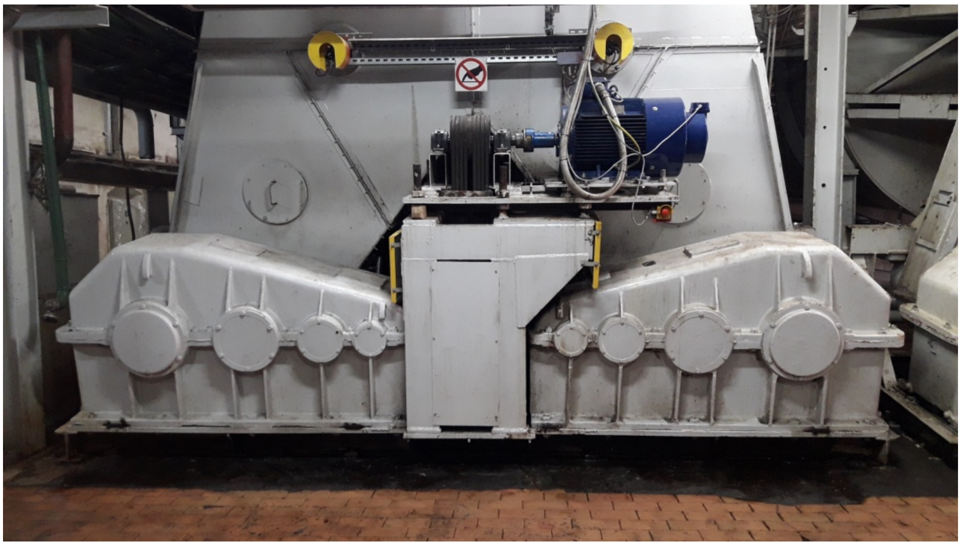

Fig. 1. Multi-phase, angle-roller gear of the type Zamech BWR304 no. 1 and 2

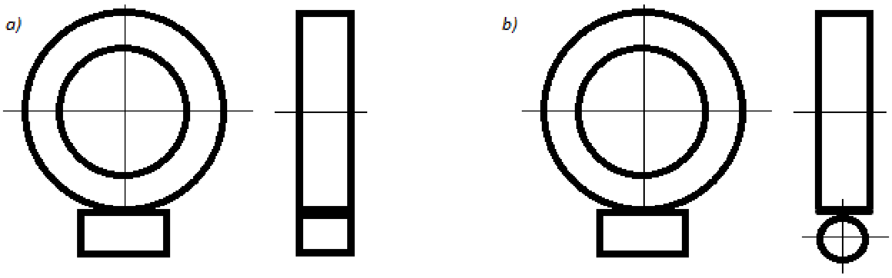

Fig. 2. Scheme of friction pair association contact for: a) Timken apparatus, b) semi-Timken apparatus

4. Research methodology

Before modification by low-friction additives, specimens were collected from each gear. They were extracted during the gear operation through a control- measurement opening. The volume of one specimen collected from each gear specimen was 60 cm^3.

Measurements of noise emission volume of gears working in unmodified oils were also performed. Due to high level of noise in the hall of a beet juice extraction and processing plant, measurements were performed at the distance of 75 cm from the central part of the gear crankcase, at the height 120 cm, over the line of the gear foundation.

For further tests, transmission oils were mixed with low friction additives. Metaltec1213 was added in gears 1 (BWR304-1) and 3 (BWR304-3) in the amount: 2% of volume. Metaltec 1213 was added to gear 2 (BWR304-2) and 4 (BWR304-4) in the amount: 4% of volume.

The amount of added modifier was accepted to be within the limits indicated by manufacturer of the low friction additive Metaltec 1213. The dose recommended to be added to gear oils 2-5%. Minimal dose is accepted to be 2% and double dose – to reach 4%.

After mixing the additives in gears, during 24 hours, oil specimens were collected again.

At the same time, cyclical measurements of noise emission were performed, as well. The first measurement was made after three hours of the gear operation with the use of modified oils, whereas, the next measurements were performed every three hours, for the period of the first 12 hours. Next, noise emission was measured after 288 hours of operation with modified oils.

After finishing the tests, modified oils were used in the gears until the end of the beet campaign without changes.

5. Tests results

The results of tests presented in Tab. 2 inform about lubricity of oils from particular gears before adding modifiers (Tab. 2, positions 1-4), and oils modified with low-friction additives (Tab. 2, position 6-9). In addition, the value of fresh oil lubricity was measured (Tab. 2, position 5).

In the last column of the table, there is a percentage increase in the oil lubricity parameter, for particular gears. In BWR304-1 and BWR304-3 gears with oil modified with Metaltec 1213 in the amount of 2% of volume, an increase in lubricity parameter by 67% and 76 was reported as compared to unmodified oil. In BWR304-2 gear with oil modified with addition of Metaltec 1213 in the amount 4% of volume, an increase by 128% in lubricity value parameter was found. In the last gear, BWR304-4 the oil was mixed in 4% of volume with Metaltec 1213. An increase by 100% in lubricity parameter value was obtained as compared to the oil before modification. It must be emphasized that the oil in BWR304-2 gear was characterized by the lowest value of lubricity parameter measured before addition of the modifier. Oils used in all the tested gears were characterized by lower value of lubricity parameter as compared to fresh oil. At the moment of the tests start, the time of the gear operation after the oil change, was estimated to be 900 hours.

Tab. 2. Friction tests results (semi-Timken apparatus)

Item	Gear	Additive	Friction load [N]	Value increase
1.	BWR304-1	–	385.00	–
2.	BWR304-2	–	360.00	–
3.	BWR304-3	–	380.00	–
4.	BWR304-4	–	380.00	–
5.	Fresh oil	–	420.00	–
6.	BWR304-1	2% Metaltec	645.00	67%
7.	BWR304-2	4% Metaltec	820.00	128%
8.	BWR304-3	2% Metaltec	670.00	76%
9.	BWR304-4	4% Metaltec	760.00	100%

In order to find the correlation of the oil boundary film durability with the level of noise emitting vibrations, measurements of the noise levels of particular gears were performed. A detailed diagram of the noise emission level changes is presented in Fig. 3. It needs to be noted that the gear work time axis has a 24-hour scale and distances of markers inform us about the successive time of testing, expressed numerically in hours, fatter application of the additive and are distributed every 24 hours.

In BWR304-3 and BWR304-4 gears, addition of Metaltec 1213 caused a noticeable change in the noise emission level within the first 24 hours after application. After another 48 hours, a further drop in the noise level was reported for both gears. The value of noise emission stabilized after 72 hours, at the level lower by 3 to 4 dB, than the initial value.

The change in noise emission right after the application was not as rapid for BWR304-1 and BWR304-2 gears. Drop in the noise emission level was reported no sooner than on the second day of monitoring. During 288 hours of noise level testing, a drop in the value of acoustic parameter by 3, down to 4 dB, was also observed for these gears.

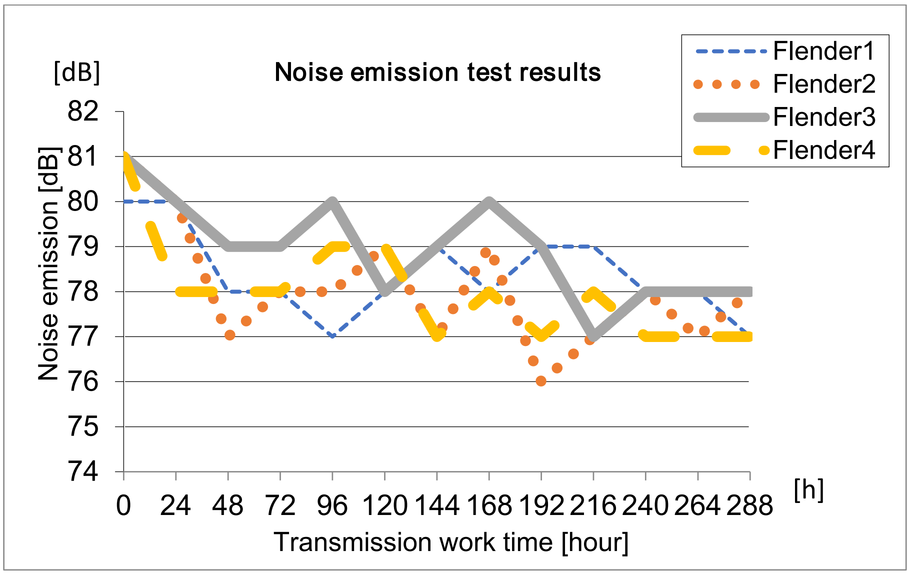

Fig. 3. Graphic presentation of noise emission tests results

Figure 4 shows the screen of SoundMeter application during the tests. Fig. 4a shows the level of noise emission of a gear with unmodified oil, Fig. 4b presents the noise emission level of a gear modified with Metaltec 1213 in the amount 4% of volume.

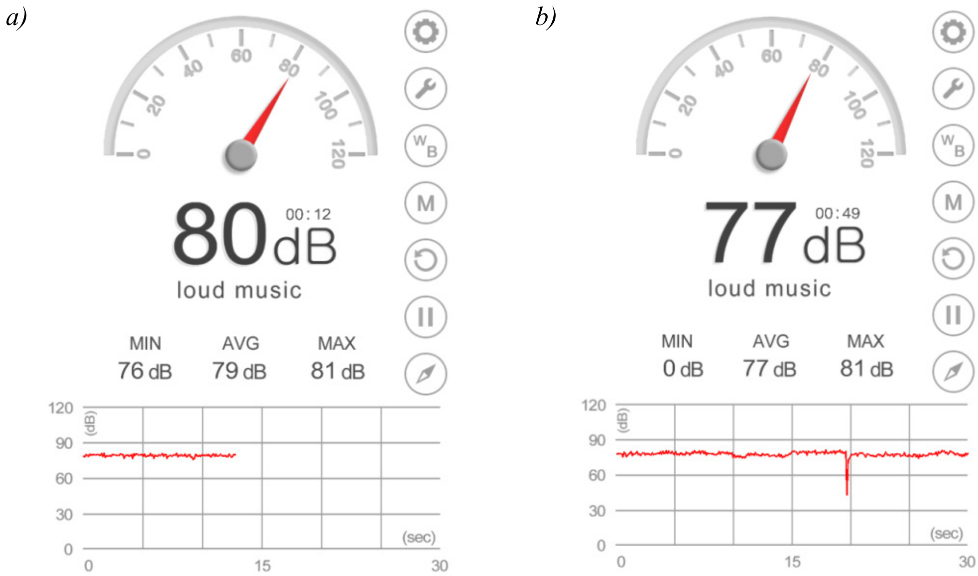

Fig. 4. Level of the gear noise emission: a) with unmodified oil, b) with oil modified by Metaltec 1213 in concentration 4% in volume

6. Conclusions

Significantly, higher values of friction loads were found for oils unmodified with Metaltec 1213. Addition of Metaltec 1213 in the amount of 4% of volume to the oil increased its lubricity parameter much better than for 2% addition. Changes in the noise emission level for mixtures of 2% and 4% are comparable which is caused by high performance of Metaltec 1213 additive. Addition of this modifier even in the amount of 2% of volume leads to creation pressure resistant boundary film.

The tests prove that each modification of oil by means of low friction additives requires a separate assessment of lubricity and the impact on the level of noise

The measured values of noise emission could be disrupted by noise from the environment as the noise made by the gear operation in a production hall were not separated from the noise produced by other machines working on the same time.

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