**EVGENY G. KUZIN** (*Prokopievsk branch of Kuzbass State Technical University*)
**BORIS L. GERIKE** (*T.F. Gorbachev Kuzbass State Technical University*)

# MONITORING THE CONDITION OF GEAR UNITS FOR VARIABLE-FREQUENCY DRIVES OF MINE BELT CONVEYORS

This study provides the results of analysis of mine belt conveyor downtime and considers the relevance of monitoring their technical condition. The monitoring results of VFD conveyor gear units regarding lube oil and vibration parameters are presented.

***Keywords:*** belt conveyor, variable frequency drive, technical diagnostics, vibration diagnostics, analysis of lubricants.

A great number of belt conveyors is currently in operation. In the near future, it is expected that their number and capacity will increase further, along with a greater transport distance for mined rock. The specific power and equipment for belt conveyors is growing and the variable frequency drive has been widely introduced. Operation of the entire plant is dependent on the conveyor's serviceability.

The growing volumes of coal mining using comprehensively mechanized long walls along with the increasing production safety require the development of reliable transport systems. High efficiency and fail-safe operation with a concurrent decrease in energy consumption is the primary challenge facing the manufacturers of mine belt conveyor lines. Another equally important task is to reduce expenses for maintenance and repair. In order to ensure fail-safe operation of the mine belt conveyor during the maximum possible time, the causes of various component failures should be determined [1−3].

Analysis of downtimes caused by the belt conveyor gear unit failure indicates from 7.4 to 18.2% of the total number of failures and amounts to 12% on average. It should be noted that the belt splice failures prevail among the total number of failures. Failures are rather frequent but the average time required for their rectification is 1.5 to 2 h. Downtime caused by gear unit failure are seldom but the average reconditioning time is from 24 to 48 h.

Therefore, identification of the actual technical condition of the mine belt conveyor gear units is a crucial task.

The study provides monitoring data of the lube oil and vibration parameters of the 3LL1600 mine belt conveyor with length $L$ = 850 m, engineering capacity $Q$ = 3500 t/h, belt speed $v$ = 0 to 4 m/s.

The conveyor drives employ Moventas Santasalo gear units:

D3RST82XO, double-reduction right-angle type;

reduction ratio $i$ = 20.6128;

rated mechanical power at service factor FS=1 $P_{\text{m rated}}$ = 995 kW;

rated thermal power at service factor FS=1 and ambient temperature $t_{\text{amb}}$ = 20ºC $P_{\text{t rated}}$ = 779 kW;

permissible oil temperature $t_{\text{oil}}$ = 90ºC;

installed motor power $P$ = 500 kW;

high speed shaft rotation speed $n$ = 1500 rpm (25 Hz).

The mining frequency converter station, type ChPSSh-1250/6-0.69-2-UHL5, is designed for step less electrical speed and torque control of the single or multi-motor belt conveyor drive and feeding the supply voltage to all station and conveyor auxiliaries in underground mining workings that fall under the gas (methane) and carbon dust hazard category as per the requirements of safety regulations [4].

The conveyors were commissioned on June 10, 2014.

Figure 1 presents the driving drum belt run-around scheme and arrangement of gear units designated conventionally as P1-P3.

Vibration parameters as a function of the belt conveyor loading and speed were measured during the two months after commissioning (Figures 2 to 4). The loading and speed data

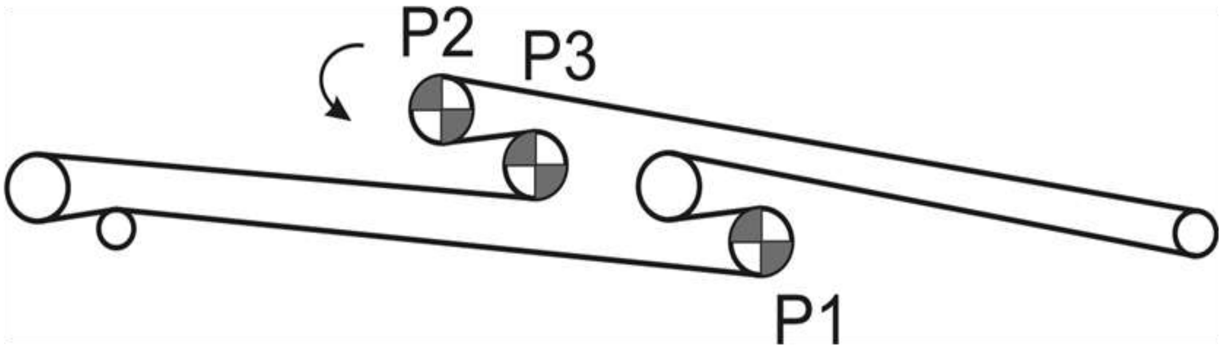



Fig. 1. Driving drum belt run-around scheme and arrangement of gear units

were recorded against the readings of the ChPSSh frequency converter station.

Having analyzed the vibration parameters, we can conclude that the gear unit P1 has the heaviest load while gear unit P3 is the least loaded, which is in line with the classical theory of calculating traction force on the belt conveyor drums [5].

A feature of the variable frequency drives is the dependence of vibration levels on the drive motor rpm [12]. At the run-in stage, the minimum vibration levels are observed for loading levels of 25 to 30%.

Then the lube oil and vibration parameters were analyzed depending on the belt conveyor operating time as per the requirements of regulatory documents [6–11].

The kinematic viscosity data are presented in Table 1 and Figure 5. The results of mechanical impurity accumulation for gear units P1 are presented in Table 2 while primary impurities for the remaining gear units are shown in Figures 6, 7.

The open-cup flash point data are presented in Table 3.

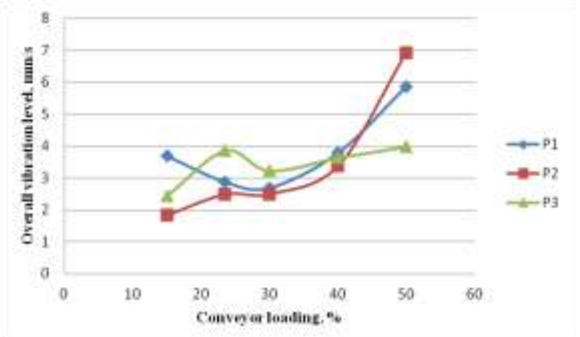



Fig. 2. Overall vibration level in 2 to 200 Hz range vs conveyor loading

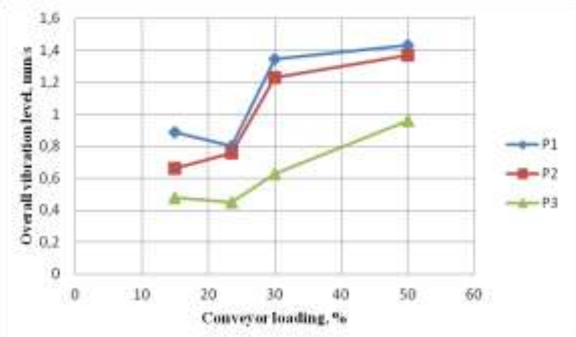



Fig. 3. Overall vibration level in 100 to 2000 Hz range vs conveyor loading

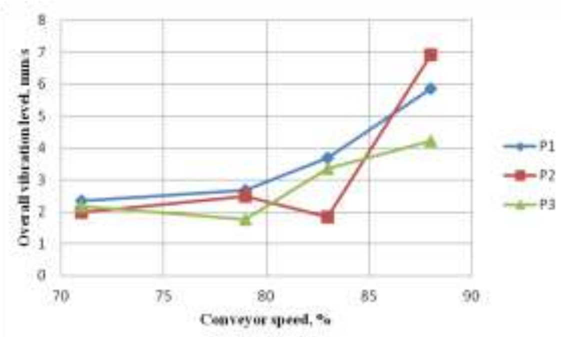



Fig. 4. Overall vibration level in 100 to 2000 Hz range vs conveyor speed

Table 1

Kinematic viscosity (KV) as per GOST 6258−85

| Gear unit | Temperature, °C | Standard value | Sample of 29.08.2014 | Sample of 19.02.2015 | Sample of 12.03.2015 | | Sample of 06.07.2015 | |
|---|---|---|---|---|---|---|---|---|
| | | KV, mm²/s | KV, mm²/s | KV, mm²/s | | KV, mm²/s | FV | KV, mm²/s |
| P1 | 40 | 320.00 | 297.70 | 307.00 | | 325.20 | 45.40 | 345.00 |
| | 100 | 24.10 | 25.33 | 24.17 | | 24.50 | 3.50 | 25.33 |
| P2 | 40 | 320.00 | 335.50 | 345.50 | | 341.40 | 46.30 | 351.20 |
| | 100 | 24.10 | 24.67 | 24.50 | | 25.83 | 3.58 | 26.00 |
| P3 | 40 | 320.00 | 304.80 | 308.60 | | 335.50 | 43.30 | 329.70 |
| | 100 | 24.10 | 23.33 | 24.67 | | 24.67 | 3.58 | 26.00 |

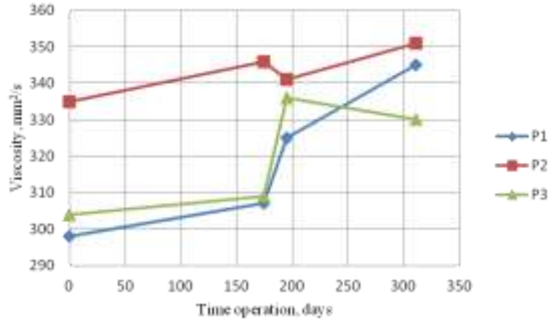



Fig. 5. Oil kinematic viscosity vs operating time

Table 2

Gear unit P1 wear products, g/t

| Elements | Permissible limits | Sample of 29.08.2014 | Sample of 19.02.2015 | Sample of 12.03.2015 | Sample of 06.07.2015 |
|---|---|---|---|---|---|
| Fe | 126–200 | 40.340 | 160.120 | 204.800 | 171.520 |
| Si | 21–30 | 37.640 | 33.880 | 44.550 | 39.830 |
| Cu | 100–150 | 5.526 | 0.480 | 8.960 | 1.650 |
| Al | 4–7 | 1.518 | 1.540 | 2.380 | 2.000 |
| Cr | 2–5 | 0.683 | 1.300 | 1.070 | 1.20150 |
| Pb | − | 2.547 | 3.450 | 4.230 | 2.480 |
| Sn | − | 5.781 | 9.340 | 7.900 | 6.980 |

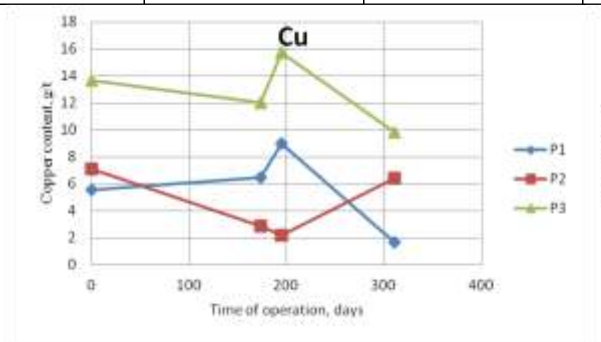



Fig. 6. Iron content vs operating time

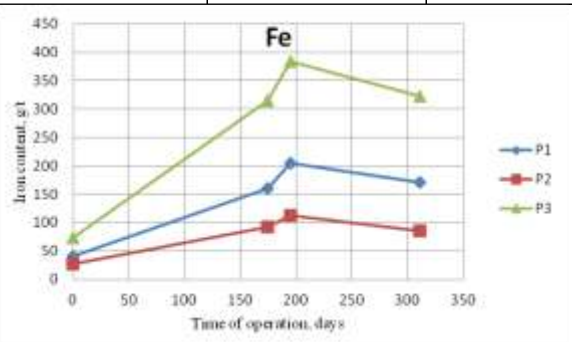



Fig. 7. Copper content vs operating time

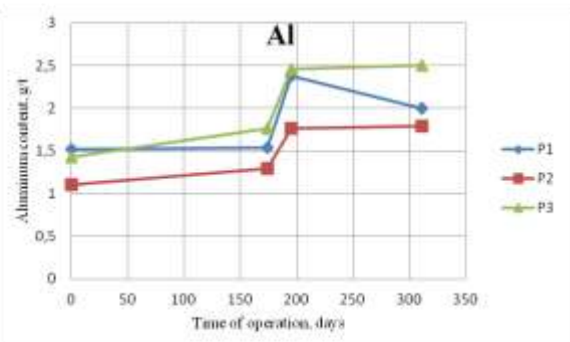
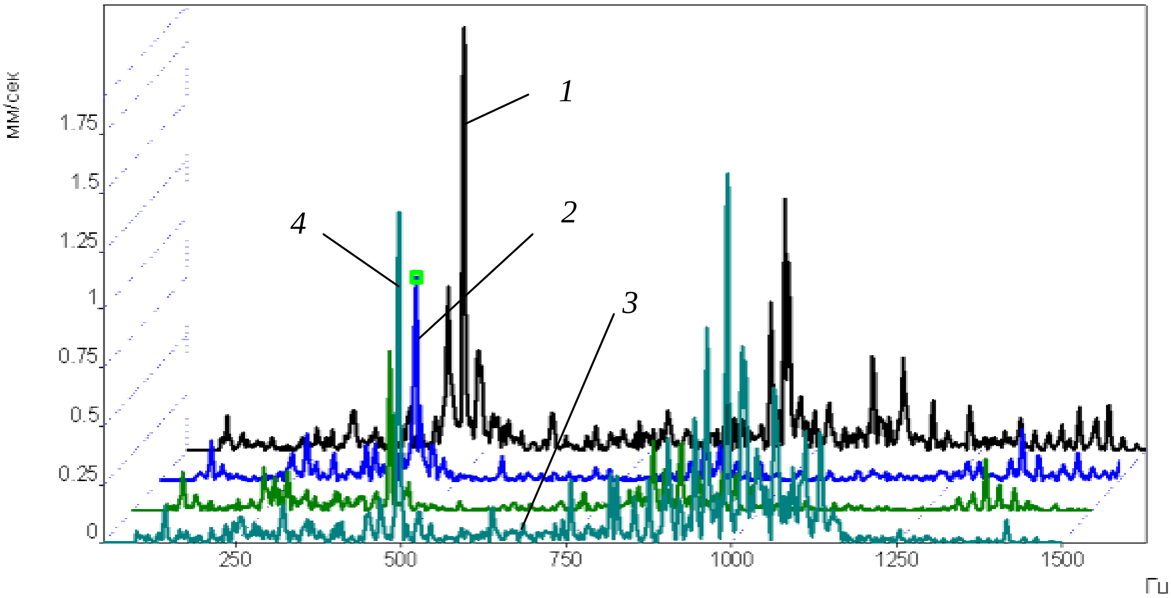



Fig. 8. Aluminum content vs operating time

Table 3

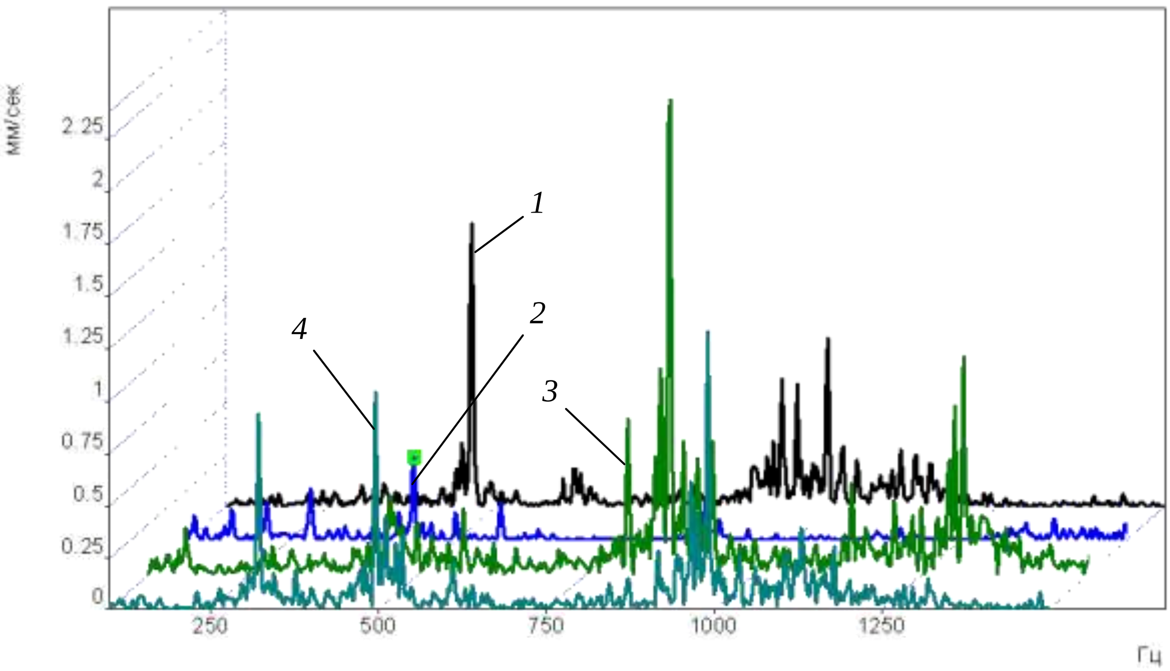
Open-cup flash point, °C (GOST 26378.4−84)

| Gear unit | Standard value (DIN ISO 2592) | Sample of 29.08.2014 | Sample of 19.02.2015 | Sample of 12.03.2015 | Sample of 06.07.2015 |
|---|---|---|---|---|---|
| P1 | 255 | 226 | 222 | 238 | 236 |
| P2 | 255 | 248 | 228 | 235 | 215 |
| P3 | 255 | 234 | 225 | 230 | 235 |



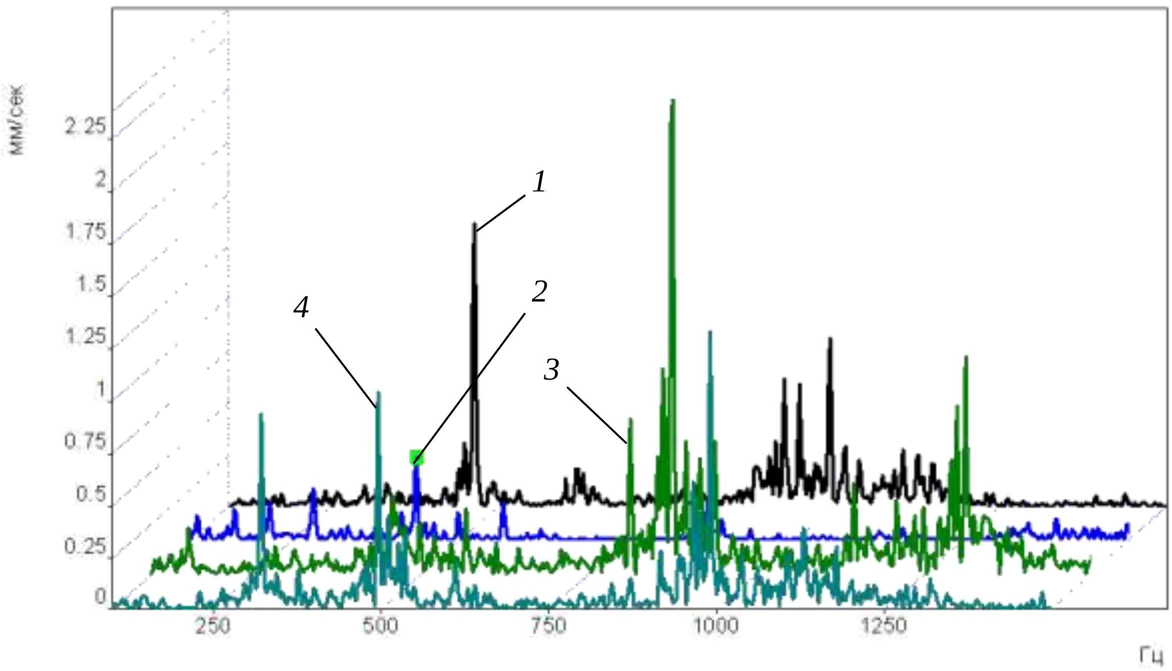

*[vertical axis: "mm/sec"] [horizontal axis: "Hz"]*

Fig. 9. Comparison of vibration velocity spectra in range from 100 to 1500 Hz for gear unit P1: *1* – 28.08.2014, *2* – 19.02.2015, *3* – 12.03.2015, *4* – 06.07.2015




*[vertical axis: "mm/sec"] [horizontal axis: "Hz"]*

Fig. 10. Comparison of vibration velocity spectra in range from 100 to 1500 Hz for gear unit P2: *1* – 28.08.2014, *2* – 19.02.2015, *3* – 12.03.2015, *4* – 06.07.2015




*[vertical axis: "mm/sec"] [horizontal axis: "Hz"]*

Fig. 11. Comparison of vibration velocity spectra in range from 100 to 1500 Hz for gear unit P3: *1* – 28.08.2014, *2* – 19.02.2015, *3* – 12.03.2015, *4* – 06.07.2015

Analysis of the behavior of oil parameters shows that viscosity rises in the course of operation owing to the evaporation of low-boiling fractions. In this case, the higher the initial viscosity, the less the mechanical impurity accumulation and the less the wear intensity of bearings and gear teeth in the gear unit (ref. Figures 5 to 8): *1* – 28.08.2014, *2* – 19.02.2015, *3* – 12.03.2015, *4* – 06.07.2015.

Figures 9 to 11 show the spectra of the vibration velocity RMS values in the range typical of gear unit tooth mesh frequencies. Measurements were performed according to [4] for a secondary shaft point in the axial direction being most characteristic of the vibration at the tooth mesh frequencies of the first gear pair.

Having analyzed the spectra (ref. Figures 8 to 10), we arrived at the conclusion that the running-in processes in the gear unit were completed, the highest vibration levels are observed in gear unit P1 with the lowest in gear unit P3.

The gear unit manufacturer, Moventas Santasalo, recommends the first oil replacement after 800 to 1000 hours of operation and subsequently after 10,000 hours of operation or annually. The first oil replacement was not actually performed, only replenishment after 5000 h. The present oil condition in gear units P1 and P2 is satisfactory while in gear unit P3 the concentrations of mechanical iron (Fe) impurities have been exceeded.

Thus, the results of the conveyor monitoring since the commissioning date enable us to select the proper condition criteria for the gear unit components as a function of its loading and speed and elaborate oil replacement recommendations depending on the gear unit location in the conveyor process scheme.

**References**

1. B.L. Gerike, I.L. Abramov, P.B. Gerike. Vibrodiagnostika gornyh mashin i oborudovaniya. Training aid. Kemerovo, 2007. 167 p.
2. Konveyer shahtny lentochny gruzopassazhirsky ZLL 1600. Operating manual. LLC "Tsentr transportnyh sistem", 2011.
3. Bartelmus W.: Vibration condition monitoring of gearboxes. Machine Vibration 1992 nr1 s.178-189.
4. Ali Rostami, Rohallah Panahi Leavoli, Jalaleddin Ghezavati, Mohommad Homaei. Gearbox fault Detection using vibration signals based on the method of Hilbert. Indian Journal of Scientific Research 1(2): p. 675-689, 2014.

5. Vasiliev K.A. Transportnye mashiny i oborudovaniye shaht i rudnikov. Training aid / K.A. Vasiliev, A.K. Nikolaev, K.G. Sazonov. – St. P.: "Lan" Publishing House, 2012. – 544 p.: il.
6. GOST ISO 10816-1-97 Kontrol sostoyaniya mashin po rezultatam izmerenyi vibratsii na nevrashchayushchihsya chastyah.
7. GOST 6258-85 Nefteproducty. Metod opredeleniya uslovnoy vyazkosti.
8. GOST 26378.4-84 Nefteproducty otrabotannye. Metod opredeleniya temperatury v spyshki v otkrytom tigle.
9. GOST P 52659-2006 Neftinefteproducty. Metod ruchnogo otbora prob.
10. GOST 25371-97 Nefteproducty raschet indeksa vyazkosti po kinematicheskoy vyazkosti.
11. GOST 6370-83 Neft, nefteproducty i prisadki. Metod opredeleniya mehanicheskih primesey.
12. J. Obuchowski, A. Wylomańska, R. Zimroz, "Recent Developments in Vibration Based Diagnostics of Gear and Bearings Used in Belt Conveyors", Applied Mechanics and Materials, Vol. 683, pp 171-176. doi:10.4028/http://www.scientific.net/AMM.683.171.

| **"Gornye nauki i tehnologii"/ "Mining science and technology", 2016, No. 1, pp. 14–19** | |
|---|---|
| **Title:** | **Monitoring the condition of gear units for variable-frequency drives of mine belt conveyors** |
| **Author 1** | Name&Surname: **Evgeny G. Kuzin**<br>Company: **Prokopievsk branch of Kuzbass State Technical University**<br>Work Position: **Senior Lecturer**<br>Contacts: **kuzinevgen@gmail.com** |
| **Author 2** | Name&Surname: **Boris L. Gerike**<br>Company: **T.F. Gorbachev Kuzbass State Technical University**<br>Work Position: **Professor**<br>Contacts: **gbl_42@mail.ru** |
| **DOI:** | **http://dx.doi.org/10.17073/2500-0632-2016-1-13-18** |
| **Abstract:** | This study provides the results of analysis of mine belt conveyor downtime and considers the relevance of monitoring their technical condition. The monitoring results of VFD conveyor gear units regarding lube oil and vibration parameters are presented. |
| **Keywords:** | belt conveyor, variable frequency drive, technical diagnostics, vibration diagnostics, analysis of lubricants. |
| **References:** | 1. B.L. Gerike, I.L. Abramov, P.B. Gerike. Vibrodiagnostika gornyh mashin i oborudovaniya. Training aid. Kemerovo, 2007. 167 p.<br>2. Konveyer shahtny lentochny gruzopassazhirsky ZLL 1600. Operating manual. LLC "Tsentr transportnyh sistem", 2011.<br>3. Bartelmus W.: Vibration condition monitoring of gearboxes. Machine Vibration 1992 nr1 s.178-189.<br>4. Ali Rostami, Rohallah Panahi Leavoli, Jalaleddin Ghezavati, Mohommad Homaei. Gearbox fault Detection using vibration signals based on the method of Hilbert. Indian Journal of Scientific Research 1(2): p. 675-689, 2014.<br>5. Vasiliev K.A. Transportnye mashiny i oborudovaniye shaht i rudnikov. Training aid / K.A. Vasiliev, A.K. Nikolaev, K.G. Sazonov. – St. P.: "Lan" Publishing House, 2012. – 544 p.: il.<br>6. GOST ISO 10816-1-97 Kontrol sostoyaniya mashin po rezultatam izmerenyi vibratsii na nevrashchayushchihsya chastyah.<br>7. GOST 6258-85 Nefteproducty. Metod opredeleniya uslovnoy vyazkosti.<br>8. GOST 26378.4-84 Nefteproducty otrabotannye. Metod opredeleniya temperatury v spyshki v otkrytom tigle.<br>9. GOST P 52659-2006 Neftinefteproducty. Metod ruchnogo otbora prob.<br>10. GOST 25371-97 Nefteproducty raschet indeksa vyazkosti po kinematicheskoy vyazkosti.<br>11. GOST 6370-83 Neft, nefteproducty i prisadki. Metod opredeleniya mehanicheskih primesey.<br>12. J. Obuchowski, A. Wylomańska, R. Zimroz, "Recent Developments in Vibration Based Diagnostics of Gear and Bearings Used in Belt Conveyors", Applied Mechanics and Materials, Vol. 683, pp 171-176. doi:10.4028/http://www.scientific.net/AMM.683.171. |